United States
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Forest Service

Southwestern
Region

Proceedings of the Workshop on Southwestern Habitat Types

April 6-8, 1983
Albuquerque, New Mexico

Dedication

This proceedings is dedicated to **William L. Stewart** whose death soon after the workshop in Albuquerque ended, is a loss to us all. Bill honored and loved his colleagues. He knew this paper would be one of his last efforts. His final months were lived as an inspiration for us to join and share together our interests, feelings, and professional respect.

COVER PHOTO: A landscape in the Rio Puerco drainage in New Mexico has mesas and colluvial slopes and a variety of alluvial slopes. Three distinct habitat types can be seen. See pages 62 and 106. Photograph - September 25, 1963.

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W. H. Moir and Leonard Hendzel
Technical Coordinators

Sponsored by:
USDA Forest Service, Rocky Mountain Region,
USDA Forest Service, Southwestern Region and
USDA Forest Service, Rocky Mountain Forest
and Range Experiment Station

Preface

The purpose of this workshop is to introduce and become acquainted with some recent concepts of habitat types that have been developed in Arizona, New Mexico, and Colorado. The meeting brings together scientists who helped develop habitat type classifications and users who will be responsible for applying the classification toward resource management and planning.

Ecological classifications applied to southwestern terrestrial ecosystems have developed considerably during the last decade. To provide clarity and perspective this workshop examines a variety of habitat type concepts and methods and several leading ecological classifications. The first forest habitat typing effort began in Arizona and New Mexico in 1973, with concurrent efforts in Colorado and Wyoming. Studies were mostly contracted between local ecologists and the Rocky Mountain Forest and Range Experiment Station. Today almost all forests in Regions 2 and 3 have been classified into habitat types.

The Terrestrial Ecosystem Survey (TES) grew out of the Southwestern Region's soil resource inventories of the early and mid 1970's. Soil scientists quickly appreciated that soils could not be described or classified apart from the vegetation and climate under which they develop. Soil inventory procedures were extended to include vegetation descriptions at pedon sites. Field data were organized and classified by techniques of gradient and community analysis used in plant ecology. The modern TES Handbook is a systematic procedure for inventorying, classifying, mapping, and interpreting terrestrial resource data. It is an "integrated" procedure because soil, vegetation, and climatic data (whenever possible) are collected simultaneously and linked by systems of both vegetation and soil taxonony. This workshop examines how habitat type and TES classifications relate to each other.

The concept of biotic communities of the Southwest grew from Dr. Charles H. Lowe's "Arizona Landscapes and Habitats", Part I of his The Vertebrates of Arizona published by the University of Arizona Press. With David E. Brown and collaborators we are now given "The Biotic Communities of the American Southwest" (Desert Plants, V. 4, Nos. 1-4) as a text to accompany the map entitled "Biotic Communities of the Southwest" (scale 1:1,000,000) and published as USDA General Technical Report RM-78, August 1980.

This workshop compares these and other concepts of ecological classifications in theory and application. Can we benefit in management from the strengths of each approach? Can we apply these approaches in non-forested (i.e. deserts, grasslands, shrublands, woodlands, or tundras) ecosystems where great differences can occur between existing and potential vegetation? Which classification is "best" for a particular purpose of the land planner or project leader?

The workshop is a joint endeavor between the U.S. Forest Service Regions 2 and 3 and the Rocky Mountain Forest and Range Experiment Station. We greatly acknowledge assistance by Frank Ronco, Earl Aldon, Ann Wolfe, Nancy Moir, and Sandra Roberts.

William H. Moir
Region 3

Leonard Hendzel
Region 2

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Forest Ecosystem Classification and Interpretation for Management of Multiple Uses in Forest and Rangeland Environments

by

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ABSTRACT.--Ecosystem classification was encouraged by legislation emphasizing ecosystems, interdisciplinary teams and integrated approaches for management. In response to this encouragement, a variety of systems of ecosystem classification have been produced. Most are based on the use of vegetation as an index of the ecosystem, while others use soils, landform or other components either singly or in some combination. Forest Service direction encourages integrated taxonomies of soil and vegetation, but accommodates nonintegrated approaches emphasizing only vegetation or other components. Flexibility in standards has been incorporated into this direction to accommodate the variety of approaches currently being used, facilitate the handling of local problems and encourage individuality. The goal is to facilitate data uniformity and interchange but not to the detriment of legitimate and needed creativity of approach.

INTRODUCTION

The National Environmental Policy Act and the Renewable Resources Planning Act, as amended, provided emphasis and stimulus to viewing lands as ecosystems and encouraged integrated land management. This emphasis, in turn, encouraged the development of ecosystem classifications which could be used as a basis of integrated land management. There have been many approaches taken in ecosystem classification, some more appropriate for management use than others. To date an ideal natural classification has not been developed for land, vegetation or ecosystems.

DISCUSSION

Need for Classification

It is appropriate to ask at this point: What are the classification needs necessary to provide a framework to successfully manage forest and rangeland environments for multiple uses? The ideal classification system must be based on readily identifiable elements of the ecosystem. It must be capable of being applied to all acres of land under management no matter what condition they are in. It must be usable to all or at least most potential users. It must provide the user with information he needs. Finally, it must have predictive value. While I do not believe we can ever build the perfect natural system to satisfy all of the above needs, I do believe workable systems can be developed. Unfortunately, contrary to the popular belief of many, the theoretically perfect natural system is just not out there waiting to be discovered.

One Potential Solution

There has been a proliferation of workshops, symposia, and literature on a wide variety of ecosystem and component classification approaches. One of the more recent workshops on land classification was held in Spokane in 1980 sponsored by the Society of American Foresters. All the individuals making presentations at that workshop had the objective of defining an ecosystem unit that could be effectively managed. All recognized that an ecosystem is a complete interacting set of organisms considered together with the environment. Yet all defined that ecosystem in a different way. Some used the component approach emphasizing vegetation, soil or landform, while others used a more integrated approach attempting to use criteria from several components. Even within a single government agency such as the Forest Service, there is a variety of approaches currently being used.

Today I would like to talk about one potentially workable solution we are pursuing.

Recognizing that uniform agreement on a common approach can probably never be achieved, the new Forest Service direction on Ecosystem Classification tries to build on what we can agree on, and accommodate the various approaches within a broad framework. We acccommodated both component and integrated approaches currently in use including vegetation, soil and landform systems and combinations thereof. The standards and criteria for soil classification and mapping are firmly established and defined in the Soil Taxonomy and soil inventory procedures, and need no further elaboration. Unfortunately, there are no firm set standards for vegetation classification or the classification of integrated ecosystem units. These are the two areas where we sought to established minimum acceptable standards within a broad framework.

Plant Associations

The classification of plant communities can be conveniently divided into systems based on potential and systems based on existing conditions. Classifications based on potential communities have also been termed natural systems, although it can be argued that existing communities can also be classified naturally. Most often, however, classifications of existing vegetation have a user or inventory bias, and as a result are somewhat artificial. Examples include classifying commerical timber land using growth potential or economic criteria, or classifying rangeland according to forage production potential. On the other hand no matter how objective one tries to be in selecting criteria to classify "natural" communities based on potential, the criteria tend to have some unnatural bias built it. For instance, in classifying forest associations, artificial criteria must be included that first define a tree and second distinguish between forested types and other community types. These decision criteria are often arbitrary criteria of convenience to the classifier rather than criteria of limits to ecosystem functioning. Similarly criteria must be included which separate types within the classification. A canopy coverage percentage for a species or group of species set by the classifier as a limit, may be arbitrary and ecologically unnatural in terms of ecosystem functioning or processes. Be that as it may, the purpose and intent in classifying communities based on potential are to develop a natural classification system. Classifications based on potential developed by two or more classifiers in the same area or region are often remarkably similar. This fact leads one to believe that useful association classifications can, and are being developed, that are close approximations of natural systems.

Even if we assume that a natural system can be developed, some potential users will undoubtedly identify reasons why it does not satisfy all their needs. Once the immediate needs of the users are satisfied, the management question will be asked in a different way with other than expected areas of emphasis. Does this negate the need for community classification or its desirability? I think not. We should view a classification as a primary system and not allow repeated modification to serve user interests to negate that classification. The classification then becomes a common framework, that provides the basis for further secondary subdivision and/or aggregation as different management questions are posed. We cannot expect a vegetation classification to answer all management questions.

If we classify communities on the basis of potential, we must also identify the relationship of the potential to the present conditions we might expect to encounter in the field. The manager must be able to characterize every acre of land according to the classification. Many of the conditions that we might encounter in the field during an inventory are disturbed and resemble each other more closely then they resemble the potential. Classifying existing conditions that resemble each other in the field as the same, often result in aggregation of lands with unlike potential. Disturbed sites more often reflect the character of the disturbance, and the time since disturbance, than site potential. Only after succession has had an opportunity to proceed for a time, does the potential begin to be more clearly reflected. The question then is how to identify potential when we inventory existing conditions. The answer clearly is that successional relationships and seral conditions must be part of the characterization of the potential communities or the system will not be usable. The assumption is that species or species combinations can be identified which will allow the user to identify the potential natural community from his inventory data.

The most prominant of the plant community classification approaches is through the use of the association concept. Various workers have employed different criteria in the development of association classifications. While the end products are not all that different, the degree of resolution of the classification and the user emphasis varies considerably. Vegetation is emphasized to the general exclusion of soil input in the development of habitat types. Other association classifications accommodate user needs and use soils as basic descriptors, but soils are generally not part of the criteria that define the associations. The new Forest Service Manual direction on classification emphasizes the desirability of a strong soil-vegetation relationship in developing association classifications as a goal, but also

accommodates single component emphasis in the development of habitat types and associations as approximations of achieving that goal.

Potential Natural Communities Versus Climax Communities

Another important consideration in the new Forest Service Manual direction is that potential natural vegetation is used to define potential rather than climax. Potential natural vegetation allows for the present existing vegetation to be projected into the future, including accounting for the effects of past disturbances, the presence of naturalized exotic species, past species extinctions and the existing climate. The concept of climax deals with the theoretical past condition of the vegetation. This past condition generally does not accommodate species extinctions, introductions of species that have become naturalized, or past disturbances that may have modified the site potential. It also assumes that the climate that produced the climax is the same that exists today. This is a shaky assumption at best. In addition the term climax conjures up a wide variety of different visions in the minds of people as to the state or condition of the vegetation. Some envision climax to be equivalent to the original, pristine, pre-colonial or even prehistoric vegetation. All such conditions are equally indefinable for the simple reason that none of us were there to record the conditions that existed, and the records of those that were, are too general, incomplete, and fragmentary for any kind of comparison, let alone a quantitative comparison. While relic sites do exist which are assumed to represent climax conditions, there is no real assurance that we can achieve such a condition again. These relics can serve equally well as examples of assumed potential natural vegetation as they can as examples of climax. The advantage of emphasizing the concept of potential natural vegetation is that where relics cannot be found, we can project the present vegetation into the future as a surogate basis of potential. This is not possible using the climax concept. While the difference may be subtle where examples of undisturbed relic vegetation exist such as some areas of the west, elsewhere in the United States, particularly here in the southwest and in the southeast, projecting existing conditions into the future is the only alternative to determine site potential. The resistance of vegetation specialists in the east to adopt the association concept, stems largely from the highly altered and disturbed vegetation that they deal with daily. Climax potential is generally not definable for their area, but potential natural conditions can be approximated by projecting the existing conditions into the future. The redefined potential natural vegetation that is used in the new Forest Service Manual accommodates these conditions and allows the vegetation specialist to deal with potential on a realistic basis. It also allows for the incorporation of stable seral plant communities of long-term duration as approximations of potential. Flexibility in this regard is both desirable and necessary. Rigid standards for determining potential would theoretically promote uniformity and facilitate comparison of data. Unfortunately rigid standards limit creativity and our ability to respond to unique situations. Standards must be flexible enough not to hamper creativity but yet rigid enough to facilitate a general level of uniformity and comparison of data.

Integrated Soil-Vegetation Taxonomy

The new Forest Service Manual also defines a kind of ecosystem classification based on potential natural communities with soil and vegetation given equal weight. The type thus defined is called the ecological type. The ecological type emphasizes a strong soil-vegetation relationship that aids in identification of the type in the field in various states of deterioration. It is keyed both to the vegetation characteristics and soil characteristics. In the absence of diagnostic vegetation, the soils can be used to help key the site to its potential. The concept of the ecological type is similar to that of terrestrial ecosystems defined here in the southwest.

In developing the Forest Service Manual direction we defined the ecological type as the ideal primary system but recognized that a variety of classification systems are being used throughout the country. It was necessary to accommodate all of them. We cannot expect to stop the world and discard all previous classifications and launch in a new direction. We must recognize the value of what has been done in the past as basic building blocks and provide the means of gradual change and accommodation as we proceed over time with the development of the ideal.

Incorporation Into Existing Inventory Systems

We must also be able to deal with the simultaneous handling of ecological systems based on potential, user systems and inventory systems. The solution can vary from data base management of uncoordinated systems through geographic locators, the coordination of systems through a universal map framework, coordination by using a universal common identifier such as classified types of an ecosystem classification, or coordination through some inventory or use identifier. Each of these options has advantages and disadvantages and vary in operability. Data management of uncoordinated systems can work, provided each of the

uncoordinated systems is itself locatable and uses the same geographic locator. The universal framework is operable, provided the users incorporate the framework as a basic criteria of delineation in the inventory. Classified types of an ecosystem classification can be used, provided the users agree on their use and incorporate them in their inventory procedures. User or inventory identifiers are also usable, but most often cause problems because the condition of ecosystems change with time, and uses change as management direction changes.

Methods of Forest Habitat Type Classification [1]

William H. Moir and John A. Ludwig[2]

Abstract.--A consistent methodology of habitat type classification has been used throughout the western United States of America. Dr. Rexford Daubenmire developed this methodology while studying the forests of northern Idaho and adjacent Washington. This ecologically based classification system identifies units of landscape (habitat) potentially supporting the same climax plant associations. Each habitat type unit has a relatively narrow range of environmental variation. Thus each habitat type can be managed as a unit. The basic steps in this methodology are initial field reconnaissance, selection of stands, precise location of sample plots, data gathering, preliminary analysis, a series of classification analyses, field testing, revised classifications, and a final classification with complete habitat type descriptions and keys.

BACKGROUND

During the last ten years forests of Arizona, New Mexico and southern Colorado have been sampled and classified into habitat types. This effort has involved approximately 1700 sampled forest stands classified into major (geographically extensive and of significant acreage) and minor (local or of small acreage) habitat types. The task of habitat type classification has been singularly constant in methodology, from initial field work to the final classification. Dr. Rexford Daubenmire developed many of the concepts and techniques while studying the forests of northern Idaho and adjacent Washington.

In the Southwest, ecologists trained, experienced, and skilled in Daubenmire's habitat type methodology have sampled stands and developed classifications. Parallel efforts and accomplishments have taken place in most states of the western United States and in several forest regions of western Canada. Thus over a major portion of the continent, there is now a very large, consistent and comparable habitat type classification. Each habitat type is a fundamental ecological unit embracing a small degree of environmental homogeneity, thus giving many interpretative possibilities. Research or management insights from a habitat type in one area can now be extended to a similar, or even identical, habitat type in another geographic area. We are at the point where knowledge about coniferous forests (and certain other forests and woodlands as well) can be pooled over almost an entire subcontinent on a systematic and workable basis. Foresters in Alberta or western Montana can compare notes with their colleagues in central Arizona or the high Rockies in New Mexico. What has been studied about elk in Wyoming from the habitat type viewpoint can be extended by inference to elk behavior and requirements in other states or regions.

To effectively utilize habitat types as an information and communication tool, it is necessary to understand that habitat types are products of a systematic and consistent methodology. This is a key point that can often avoid endless discussion and difference of opinion concerning the concept of habitat type as a mere abstract definition. No matter what we might think a habitat type is, or should be, the actual description of a habitat type results from the application of a consistent fieldwork and analytical set of procedures that are widely accepted and uniformly practiced. The product and its manner of construction cannot be separated.

This paper summarizes the methods that we employed in habitat type classification of forests in Arizona, New Mexico, and southern Colorado.

HABITAT TYPING METHODOLOGY

The habitat typing method of classification has been developed by practicing field ecologists over the past 30 years. The most important ideas and practices began with Daubenmire and Daubenmire (1968), with improvements and refinements added at various times (Franklin et al. 1971, Pfister and Arno 1980). The methodology can be segmented into a number of tasks that are consistently performed for each forest region to be classified. These segments are: reconnaissance, selection of stands to be sampled, location of plots, data gathering, preliminary analysis, a series of computer analyses and revised classifications, field testing, final classification, and final descriptions of the habitat types with keys.

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[1]Paper presented at the Workshop on Southwestern Habitat Types, Albuquerque, New Mexico, April 6-8, 1983.

[2]William H. Moir is Region 3 Ecologist, USDA Forest Service, Albuquerque, New Mexico and John A. Ludwig is Professor of Biology, New Mexico State University, Las Cruces, New Mexico.

Reconnaissance

Reconnaissance is an orderly procedure to gain overall familiarity of forest vegetation in a large or small region. National Forest and topographic maps are essential. Reconnaissance determines the variety of forests, their seral conditions, and locations in a rapid manner without the encumbrances of data taking.

The best way we found to study forest vegetation in its detail and complexity was to get into the forested landscape on foot. We travelled cross country along road segments, by trail or otherwise to observe both stable and changing forest vegetation. Our path spanned the important discontinuities of the landscape, particularly variations in soils, geology, landforms, and microclimates.

Certain environmental features relate to observed shifts in the composition of the vegetation. Since it is not possible to keep track of the many plant species during the traverse, we paid particular attention to the dominant species. These are trees, shrubs and herbs with the greatest cover or density. Whenever we saw a pronounced shift in the cover or density of any of these dominant species we considered ourselves to be in a new stand.

Selecting Stands

A major consideration in stand selection is that stands eligible for sampling must be mature forests relatively free from signs of recent disturbance. Stands in advanced stages of succession have characteristic age and size distributions of tree populations which reveal the stable state or climax composition. This composition is generally not obvious in early succession stages. Common disturbances include logging, grazing by domestic livestock, recent fires, or in some cases prolonged fire suppression, and recreation. Of course what comprises a "serious" disturbance is a matter of judgement and experience. It is extremely helpful to have information on land use history for the area under reconnaissance. Historical records also give clues to the structure and composition of old growth or late successional forest vegetation. Stand selection was ultimately a judgement that tree, shrub, and herb layers express the essential dominance relationships of the potential vegetation for that site. The criteria of "minimum disturbance" implied that each of these layers was more or less dynamically stable under a local environment relatively unmodified by European man. In practice this means an evaluation for any evidence of logging, signs of livestock, accelerated soil erosion, or any other recent sign of man's activities that displace the dominant species from their stable or climax state.

Locating Plots

A plot is a sample of a forest stand, which is considered a homogeneous entity. There are several ways to locate plots in a stand. A number of plots can be randomly placed within the stand considered as a homogeneous entity. The essential features of the stand are then obtained as averages over the plots. This procedure is usually impractical. Instead, we deliberately locate a single plot within the homogeneous stand to best reflect the vegetation potential. If the entire stand was already near this potential, then the plot was positioned to reflect the modal vegetation characteristics as well as the typical environmental features. For example, if our reconnaissance of a stand suggested that a particular graminoid species averaged around 20% cover and mature trees were widely scattered, then we tried to locate the plot to reflect these features, not extremes in density or cover. Similarly, if reconnaissance suggested that this stand type was mostly an upper slope forest, the plot would be situated on an upper slope rather than a ridgetop where minor extensions of the stand might be found. Notes would indicate that portions of the stand extend onto the ridgetops.

In most cases an experienced field worker can capture with a single plot the essential features of a stand. However, there are some cases where vegetation patchiness is an inherent feature of stand homogeneity and is of sufficient scale relative to the plot size that a single plot is inadequate. In this case plots would be located within both the patch and gap phases of the vegetation mosaic.

Upon completion of plot description, as described below, it was necessary reexamine the stand to record anything special that was not observed in the plot, including variations in stand composition and structure.

Data Gathering-The Analytical Plot

Plot Configuration

A 25 x 5 m rectangle is permanently staked at each corner with the long dimension parallel to the slope contours (figure 1). Inside each 25 meter line twenty five quadrats each 2 x 5 dm (0.1 m^2 area) are located at 1 meter intervals commencing 0.5 m from the stakes to the center of the 2 dm side of the quadrat. Two additional 25 x 5 m rectangles are added to each side of the original to produce a 25 x 15 m macroplot divided into three equal 5 m wide strips.

Tree Measurements

In each 25 x 5 m strip all living trees from established seedlings (larger than about ankle height or 1 dm tall) to the largest specimens are tallied by 2 inch (5 cm) diameter classes as measured on all breast height (1.4 m above the ground) stems (d.b.h.). Trees smaller than 2 inches d.b.h., which includes established seed-

lings and small saplings, are tallied into height classes less than 4 1/2 feet (1.4 m) tall and greater than 4 1/2 feet (1.4 m) tall. Standing dead trees are identified by species or genus, if possible, and tallied by 2 inch (5 cm) d.b.h. classes. Seedlings or root sprouts smaller than 4 inches (1 dm) are counted in each of the 2 x 5 dm quadrats.

Shrubs and Herbs

A 2 x 5 dm quadrat frame is carefully placed at each quadrat location (figure 2) without distorting vegetation structure. The canopy coverage method is employed to measure living shrubs and herbs above the quadrat frame (Daubenmire 1959). A record is made of each species or taxon by visually estimating canopy coverage into one of the seven cover classes:

Class	Canopy Coverage (%)
0	less than 1
1	1-5
2	5-25
3	25-50
4	50-75
5	75-95
6	more than 95

The quadrat frame is painted in a manner that facilitates rapid and repeatable visual estimates of vegetation into these classes. However, it is not precise for measuring taller shrub canopies overhead, and can be restricted to measuring vegetation cover between eye level and the ground surface. Such restrictions should be noted on the data form if consistent observations are to be made by different workers. The taller overhead shrubs can be measured by presence (cover class 6) or absence (blank on data sheet) vertically above each of the 50 quadrat locations.

When shrub or herb coverages are markedly affected by seasons of growth, these measurements should be made as close as possible to the time of maximum foliar expansion of the dominant species. We found the best time for measurements of understory vegetation to be from mid July to early September in most forests of Arizona and New Mexico.

Not all of the shrub or herb species within the 25 x 15 m macroplot will be sampled in the 50 microplot quadrats. Vascular plants within the macroplot are recorded for constance on the data sheet if they remained unsampled in the 2 x 5 dm quadrats. In addition some of these constant species may have appreciable canopy coverage. The sample error involved with the systematic placement of 50 microplot quadrats can be large if certain species exhibit patchy distribution within the macroplot. In such case it is useful to record a visual canopy cover estimate for constant species that are either undersampled or oversampled by the 50 microplot quadrats.

Plants within the forest or woodland stand but outside the macroplot are recorded for presence on the data sheet. No attempt is made to estimate coverage of presence species since the size of the stand is uncertain and variable from site to site.

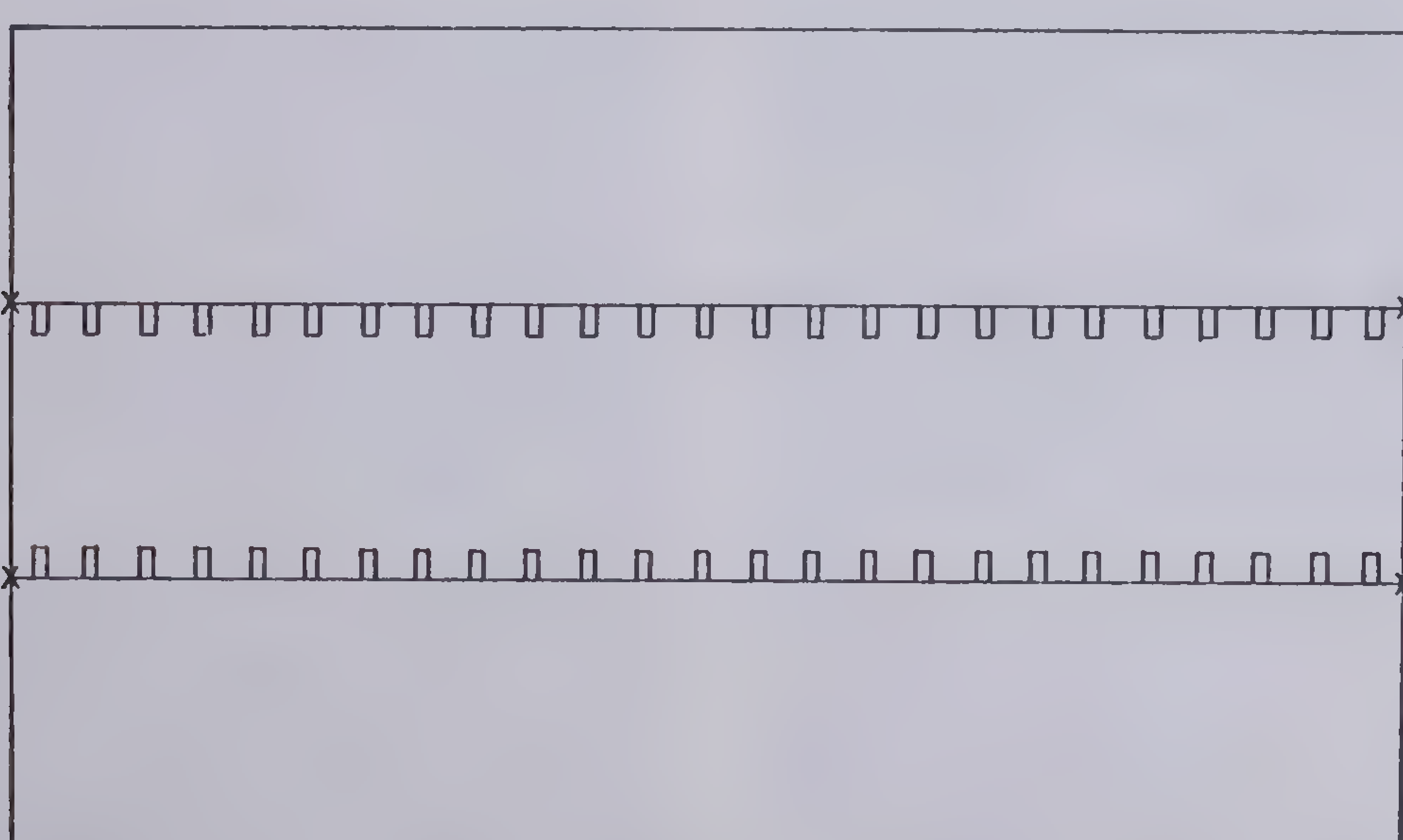

Figure 1. Layout of the 25 x 5 meter analytical plot. Permanent stakes are located at X. The position is shown of fifty 2 x 5 dm microplots at 1 meter intervals inside the central strip. The long dimension of this macroplot is approximately parallel to slope contours.

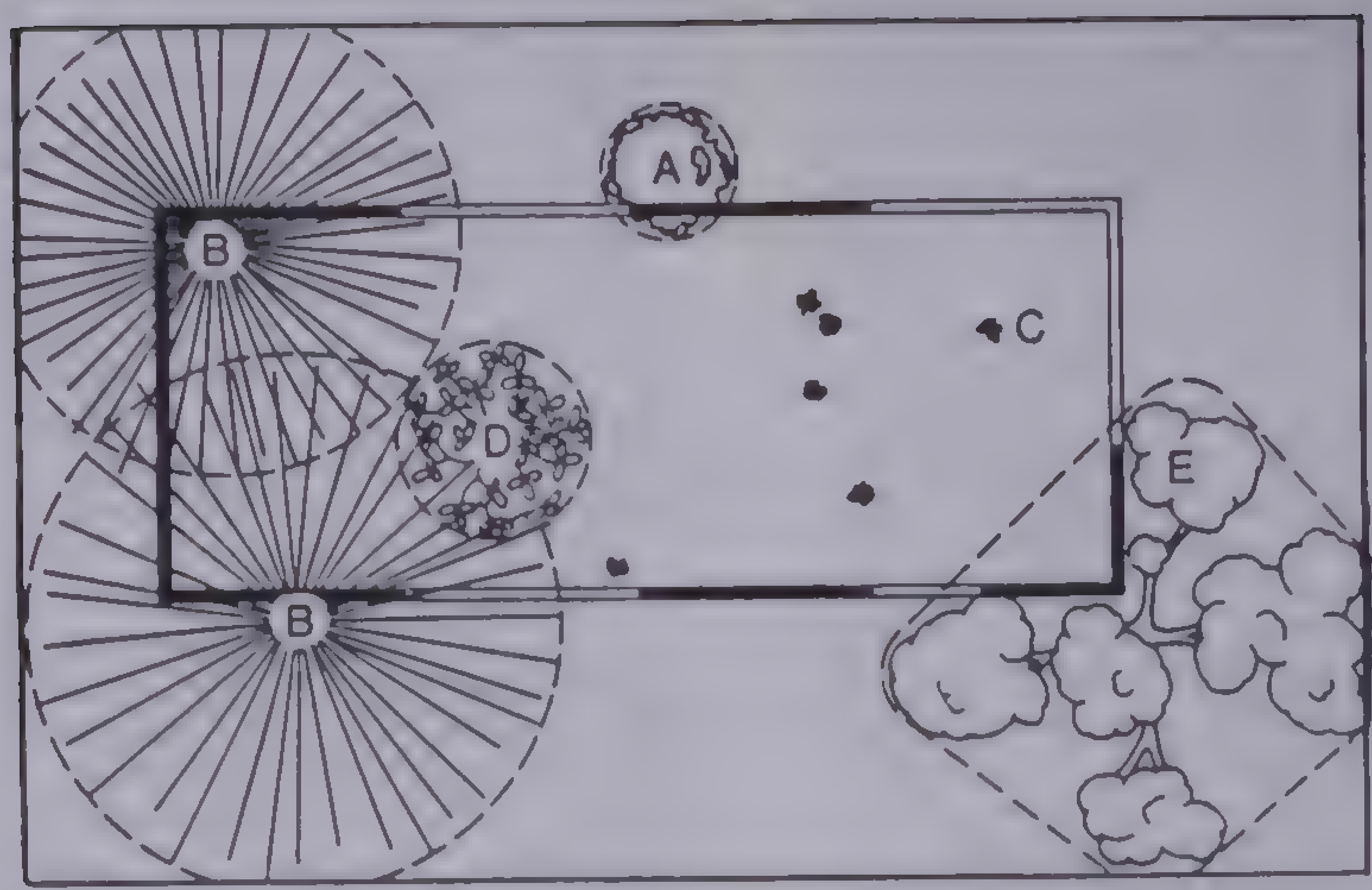

Figure 2. Canopy coverage is defined as the percentage of the horizontal surface below the vertical projection of the foliar portions (ignoring inflorescences) of plant canopies. The canopies are projected onto the horizontal plane using imaginary polygons which circumscribe the foliar mass ignoring small gaps in branch and leaf arrangement. The quadrat frame (redrawn from Daubenmire 1959) is used to estimate canopy coverage classes aided by the painted sides of the frame which lay out areas of 5, 25, 50, 75, and 95%. Cover classes of the species shown are: A, < 5%; B, 25-50%; C, < 5%; D, 5-25% and E, < 5%. Inside dimensions of the frame are 2 x 5 dm (about 8 x 20 inches).

Data Gathering-The Reconnaissance Plot

Plot Configuration

The plot center is marked by a wooden stake with the plot number recorded on it. Radii (10.9 m or 35.8 feet) are then extended like spokes on a wheel in order to flag the circular circumference with plastic tape. The area defined is the same as the analytic plot (375 m^2).

Vegetation Measurements

The tree populations within the circular plot are recorded in the same manner as described for the analytic plot. The circular plot is partitioned into arcs for convenience in keeping tree tallies without duplication or omission within the 375 m^2 area. Seedlings less than about ankle height are not tallied.

Understory vegetation is recorded by ocular judgement over the entire plot rather than by use of 2 x 5 dm microplots. These estimates are statements of canopy coverage of each understory species that would be measured if the analytic plot were superimposed. Accuracy and consistency in performing these whole-plot coverage estimates are developed through the training exercises of calibration, consensus, and independent comparisons (Pfister and Arno 1980). It is essential that these training exercises be performed throughout the sampling season even among trained and experienced workers. Accuracy of visual, whole-plot canopy coverage estimates are achieved and maintained during the field season only by calibration to the analytic plot procedure. Such calibration is virtually synonymous to "experience". In essence, reconnaissance vegetation measurements are rapidly performed statements about what coverage values would be revealed if measured by the analytic technique. Therefore, the estimates and their accuracy from each worker are fully verifiable. Further details on calibration and training exercises as well as accuracy, precision, and repeatability are given in Terrestrial Ecosystem Note 2550-29 (U.S. Forest Serv. 1982). Our field crews generally recalibrated their ocular estimates at least every 5th plot at the start of the field season and about every 20th thereafter.

All vascular plants within the circular plot are recorded by species and canopy coverage. Minor or infrequent species are recorded to the nearest tenth of a percent depending upon life form and the likely probability of "hitting" such a species in the hypothetical configuration of 50 microplots of the analytic procedure. Rare plants in the circular macroplot are unlikely to be sampled by the 50 microplot configuration and are simply recorded as constant and given the arbitrary coverage value of .01%. Plants within the stand but outside the reconnaissance plot are recorded as present but not assigned a cover value because the stand size is indeterminate.

Data Gathering-Environment & Site Characters

The exact location was marked on a 7.5 minute topographic quadrangle map. We observed the slope, aspect, and position in the landscape. Elevation was usually determined from the topographic map. The surficial geology was ascertained from available geologic maps coupled with our best ability to identify on-site rock types. Rock or soil parent material samples were occasionally collected for determination or verification by geologists. Statements about soils were limited to the competence and training of the field workers. At the very least we recorded depth to lithic or paralithic contact, texture (including the content of rock fragments in the profile), eroded condition, and surficial properties (litter, exposed soil, rock armoring, etc.).

If trained in soils, the field crew could describe reconnaissance soil pits. This was sufficient for a 'best guess' classification to the Subgroup level of soil classification (USDA Soil Conservation Service 1975). This was coupled to information about soils of the region.

In most plots site index trees were chosen for age and height measurements. The disturbance history of the stand was recorded, noting occurrence of fire scars, insects, mistletoe, evidence for logging, livestock or wildlife use, recreational evidence, dense thickets resulting from fire suppression history, etc. Our notes also included the nature and topographic relationships of ecotones and large-scale vegetation mosaics, including seral communities.

In general, these environmental and site observations required about a half hour's time on the part of one field worker. The additional time for a reconnaissance soil profile description was about a half hour.

Preliminary Analysis

At the conclusion of the field season there were two time consuming but essential jobs. Plants collected in the field had to be identified and vouchers deposited in herbaria. Most of our plant vouchers are deposited in the herbarium of New Mexico State University, Las Cruces. Secondly, data from field sheets needed to be transcribed to computer coding forms for subsequent data entry, analysis, storage, and retrieval.

While the above tasks were being performed, we constructed initial vegetation groupings by the releve method of vegetation classification (figure 3). A releve is simply a vegetation table whose plots have similar features of climax tree dominants or codominants as well as common dominant understory species (Shimwell 1971). Our initial, subjective concepts of habitat types emerged from this formulation of tables. At this point, many plots could not easily be assigned to one or another table. We had little concept of how much vegetation or environmental variation was consistently allowable from one group of plots to another.

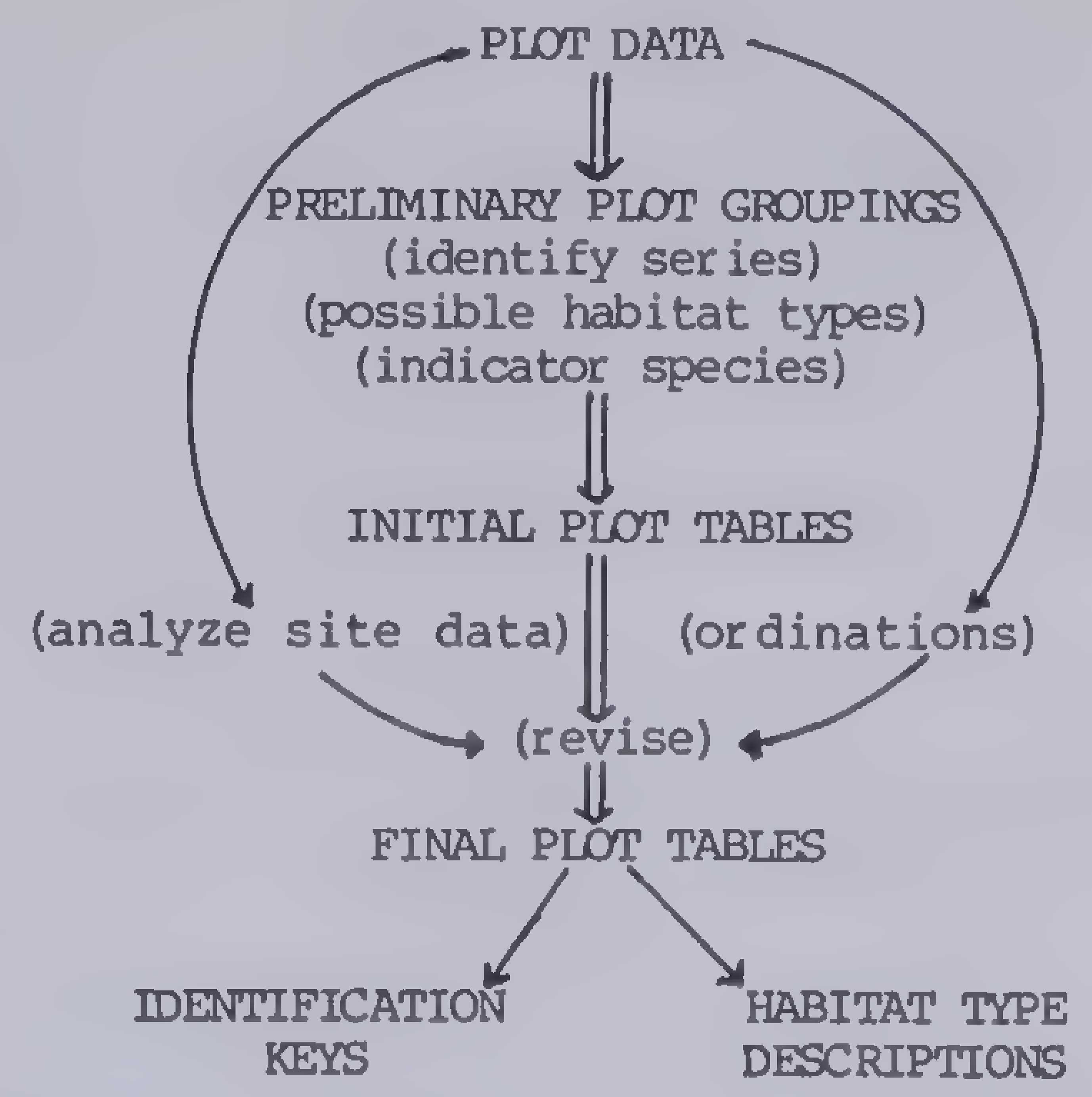

Figure 3. Strategy for developing habitat types from the plot data.

Computer Analyses

A wide variety of vegetation analysis programs are now available for habitat type classification. These include both ordination and classification programs (for general review see Ceska 1981, Noy-Meir and Whittaker 1978, Orloci 1978). A variety of programs, including cluster analysis and principal component analysis, was developed by one of us (JAL) following this tradition of mathematical plant synecology. These programs assist us in defining, revising, and displaying vegetation groupings. Computer generated tables also greatly assist in revising the releve tables, since anomalous plots become more apparent.

The results of computer analyses are seldom definitive in themselves, but are coupled to the experience and intuitions of the field ecologists. Thus, the habitat type classification process is a successive set of better and better approximations and revisions until the plot groupings satisfy the intuitions gained in the field. These plot groupings are now regarded as provisional habitat types.

Most of the habitat type classifications in the Southwest are the product of two or more field seasons of data collection. The second and later years are needed to test these preliminary results, enlarged data bases, and examine the breadth and completeness of the vegetation variation encompassed by the emerging classification. For major habitat types we prefer at least 10 plots as the sample base. For minor habitat types at least 5 plots to desirable to reveal floristic and environmental variation. However our sampling requirement of "minimum disturbance" in mature or late successional stands sometimes makes it impossible to find the desired number of plots.

Necessarily then, we have defined some habitat types with fewer than 5 plots. We know a few habitat types represented by no plots.

We do not include early stages of succession in our analyses or field testing. We do not confound time with spatial variation of forest vegetation in a habitat type classification. The classification is as comprehensive a catalogue as we can find of mature forests at or nearing their potential vegetation expression uncomplicated by man's influence. However, these forests cannot be considered pristine, climax, primeval, or without some outside influences, since all ecosystems are open systems of an Earth biosphere dominated by man.

Final Classification and Writeups

Knowledge is never complete, but at some point further efforts to gain more information about our forests becomes impractical. Classifications always need more polish, but we need to use and test what we already have. Thus, a "final" classification is simply the best we can come up with for a given increment of time and expense. The final classification is nothing more than the limit of our ability to describe forests at an instant of time. Such description is in the form of the writeups backed up by computer generated tables that display the data basic for documentation.

A habitat type is an abstract generality. It is not real, it cannot be observed. It is a data-based abstract model, if you will. Any existing forest stand can be measured or described by the same units and dimensions of the model, and that description can be related in some "best" way to its most "similar" model which is the habitat type to which that stand "belongs". If a particular stand description does not "fit" any model, then the units or dimensions of the stand may be different. For example, the stand might exist in a very disturbed, early seral condition such as a young clearcut opening. Or the model in its totality, the overall habitat type classification, may beincomplete. However, most forest stands that are described by the appropriate units and dimensions discussed in this paper, will fit into the habitat type classification. The writeup is the vehicle for applying the classification to any particular mature and minimally disturbed stand.

For each habitat type, the writeups include the distinctive and diagnostic vegetation features, a key to the field identification of forest stands, the geographic distribution of each habitat type in the Southwest, the associated environmental features, successional status of the trees, commonly observed successional stages, adjoining (ecotonal) habitat types, and similar or related habitat types in other regions. Sometimes the writeups will include known management implications gained on the basis of field knowledge.

Documentation that accompanies each writeup includes plant association summary tables, tables of location and site data for each habitat type, and a plant list of all the species in the entire plot set. Additional documentation not necessarily accompanying the writeup includes photos of each plot and releve or plot tables for each habitat type. This information is available from the authors and is public information.

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Classification of Shrub Steppe Habitat in the Northern Rocky Mountains[1]

W. L. Stewart and W. J. Hann[2]

ABSTRACT

This paper is a summary of the ecological concepts and definitions, land and plant community classification methods, and status of classification in the Northern Region. The basis to classifying land, relative to its potential climax or stable plant community and seral plant communities, is the plant species populations. Plant species respond to variability in environment, disturbance or treatment, and to competitive interactions during succession or stand development. A community type is classified by grouping stands with similar floristics and species composition. However, in order to identify community types, diagnostic species are selected that have indicator value relative to a certain environment and/or seral condition. The number of species selected as diagnostic can have a major impact in the number and variability of the community types.

Most of the forest habitat types have been classified in the Northern Region. Much of the grass and shrub steppe habitat types have been or are being classified. Riparian and alpine habitat type classification methodology has been tested, but few classifications have been developed.

Seral community type classifications have been developed on a test basis for several habitat types. Each seral community type has an ecological and resource value condition along with other predictable attributes. Once a classification is completed, a manager can key out a stand and without any further analysis will know the ecological and resource condition values, the probable future development of the stand, and its predicted response to a treatment, disturbance, or management system.

INTRODUCTION

Classification of vegetation and land has been and will continue to be a subject in symposiums, workshops, and literature. It is the basis for discussion of variability and stratification for inventory, analysis and information storage and retrieval. There is some disagreement in the area of terminology and methods, but the common goal is to classify in a logical manner that reduces variability of vegetation and land to an acceptable level. The disagreement concerning terminology and methods is acceptable, and in fact desirable, since concepts must be tailored to fit regional needs and philosophies. Universities and other research and teaching groups have a strong impact on development of terminology and methods within a regional area. We should cross reference and compare classification terminology and methods to keep terms unique and to make shifts from one regional area to another easily understood. However, to try to force fit and standardize systems that have not yet been tested for different regions may result in a loss in confidence for terminology and methods that may be well suited for one regional area but not for another. As more of the variability in vegetation and land is evaluated, it is natural that the terminology and methods can be standardized similar to the effort in soil classification that produced Soil Taxonomy (Soil Survey Staff 1975).

It is very important that terminology established in the literature concerning ecological principles and concepts not be misinterpreted or changed to meet another need. This terminology has developed over the years and should not be used to reflect what is considered to be a new principle or concept. If there is need for new terminology, then new terms should be developed, but definitions of established terminology should not be misconstrued to meet a different need or situation.

In the Northern Region of the Forest Service Dr. Rexford Daubenmire, Professor Emeritus of Washington State University, has had considerable impact on the terminology and methods used in classifying vegetation and land associated with vegetation and its potential. His standardization of the terms and methods for classifying associations provides the basis for both a vegetation and land classification. Dr. Robert Pfister, Research Director at the University of Montana School of Forestry, has had a strong impact in refining habitat type classification methodology and in developing methods to summarize management implications. Considerable work by others has added to our understanding of principles and variation of potential vegetation. The relationships of disturbed existing vegetation to undisturbed stable vegetation has been studied by many investigators. Our present philosophy in terms of classification of disturbed existing vegetation has been greatly influenced by Dr. Minoru Hironaka, Professor of Range Resources at the University of Idaho, and Dr. Steve Arno, Research Ecologist at the Intermountain Forest Service Research Station.

No single type of classification meets all needs or reduces variability in the manner desired for all types of stratification. However, the ecological classification of vegetation and site potential should be integrated to easily categorize and relate classes of disturbed existing vegetation to their undisturbed stable potential. Land classification based on the sites with potential to produce a given type of undisturbed stable (potential) vegetation should cross reference to land

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form, soil, and climate classifications. These four classification systems, when cross referenced, can provide a highly useful information system. The work done by Driscoll et al. (1982) in relating different types of classifications and in standardizing a general hierarchy and terminology provides an overall summary of the different systems. However, the relationships between components must be interpreted in order to integrate the information to produce an operable information system for management of ecosystems (Bailey 1980).

It is often expressed that inventory should be an integrated effort. For instance, when inventorying a forested area, a team should be put together consisting of multi-resource expertise (forester, range conservationist, wildlife biologist, soil scientist, plant ecologist, etc.) to map integrated units and describe all the attributes of that unit necessary for management. It is our opinion that this is not a realistic or efficient procedure. Each specialty has classification and descriptive procedures that best fit that specialty. Integrated units usually are a compromise that don't fit any specialty well. However, if the classification and descriptive methods are cross referenced and relationships integrated, then a very effective system is available. If the various classes of soil, landform, and climate are known that occur in one class of land that supports one type of undisturbed, stable (potential) vegetation, we know a lot more about that class and its relationship to the other classes than if a multitude of compromise classes are developed that supposedly integrate all the variation into individual units. This is not to say that integrated units are not useful from a general planning context, but it should be realized that they often contain considerable unpredictable variability, or if variability is reduced, then a larger number of classes result with a lack of good differentiating criteria.

In this paper we do not intend to discuss the upper levels of the heirarchial systems. We are primarily concerned with classification and relationships of plant communities and their environment at a level where response of a site and its vegetation to a given treatment or disturbance is relatively uniform and predictable.

CONCEPTS AND DEFINITIONS

Plant Species Populations

The process of classification often tends to categorize vegetation units such that investigators and managers think of each unit as an entity in itself. At one time the holistic viewpoint was popular which likened a plant community to an organism (Clements 1928) or quasiorganism (Tansley 1920). However, the actual attributes of plant communities are the individual plant populations of which a relatively uniform population is a species, subspecies, or ecotype. A plant species consists of groups of morphologically and ecologically similar natural populations, which may or may not be interbreeding, but which are reproductively isolated from other such groups (Barbour et al. 1980). Subspecies may be classified based on differences within species morphological characteristics.

Populations within one species often develop different genetic adaptations in response to different physical, biotic, and geographic environments (Hiesey and Milner 1965; McMillan 1969). This is known as ecotypic variation if populations continuously change, or as ecotypes if populations are discrete. Populations often differ both genetically and morphologically and the subspecies will be an indicator of a particular environment. For purposes of vegetation study, an identifiable relatively homogenous plant population either a species or subspecies, is identified as an attribute. In this paper the term species will be used in general for both species and subspecies attributes.

The distribution of a plant species is a function of the reaction of its populations to geographic barriers, the physical environmental complex, their ability to distribute propagules, interactions with other plants, and reactions to various disturbances (Billings 1952; Mueller-Dombois and Ellenberg 1974; Miles 1979). If the factor of disturbance is removed and plant populations stabilize, their distribution is related primarily to their amplitude to survive in varying physical conditions and compensating physical environments (i.e. shallow soil, north slope similar environment to deep soil, south slope). The amount of a species population present on a given physical environment is related to its vigor, which is a function of its ability to interact and compete with other species populations under a set of physical parameters. Many species have wide amplitudes, while others have narrow amplitudes. Species that occur predictably in noticeable amounts over a relatively narrow range often have indicator (diagnostic) value for a general type of plant environment.

When disturbance to a community creates an unstable relationship between species or is a selective detriment to the vigor, reproductive capacity, or survival of one or more species, these amplitudes change. Some species may not be able to survive in disturbed environments or with certain types of disturbance, while other species may only survive without disturbance. Many species are present in both disturbed and undisturbed conditions, but increase or decrease depending on lack of disturbance or type, intensity, and frequency of disturbance.

In order to visualize the theoretical distribution of plant species, we can assume that the multivariate number of factors creating different combinations and amounts of the various species can be reduced to a single axis which is a synthesis of these multivariate factors. An example of species distributions is given in figure 1 where the lower part of the figure shows the distributions of four species along a multivariate ecological axis, which doesn't include effects of disturbance. This axis would be a synthesis of physical environmental factors, interactions with other plants, and reproductive properties of each species for a given geographic area. Species

A, B, and C vary in amounts and presence along the length of the axis. Species D does not occur without disturbance.

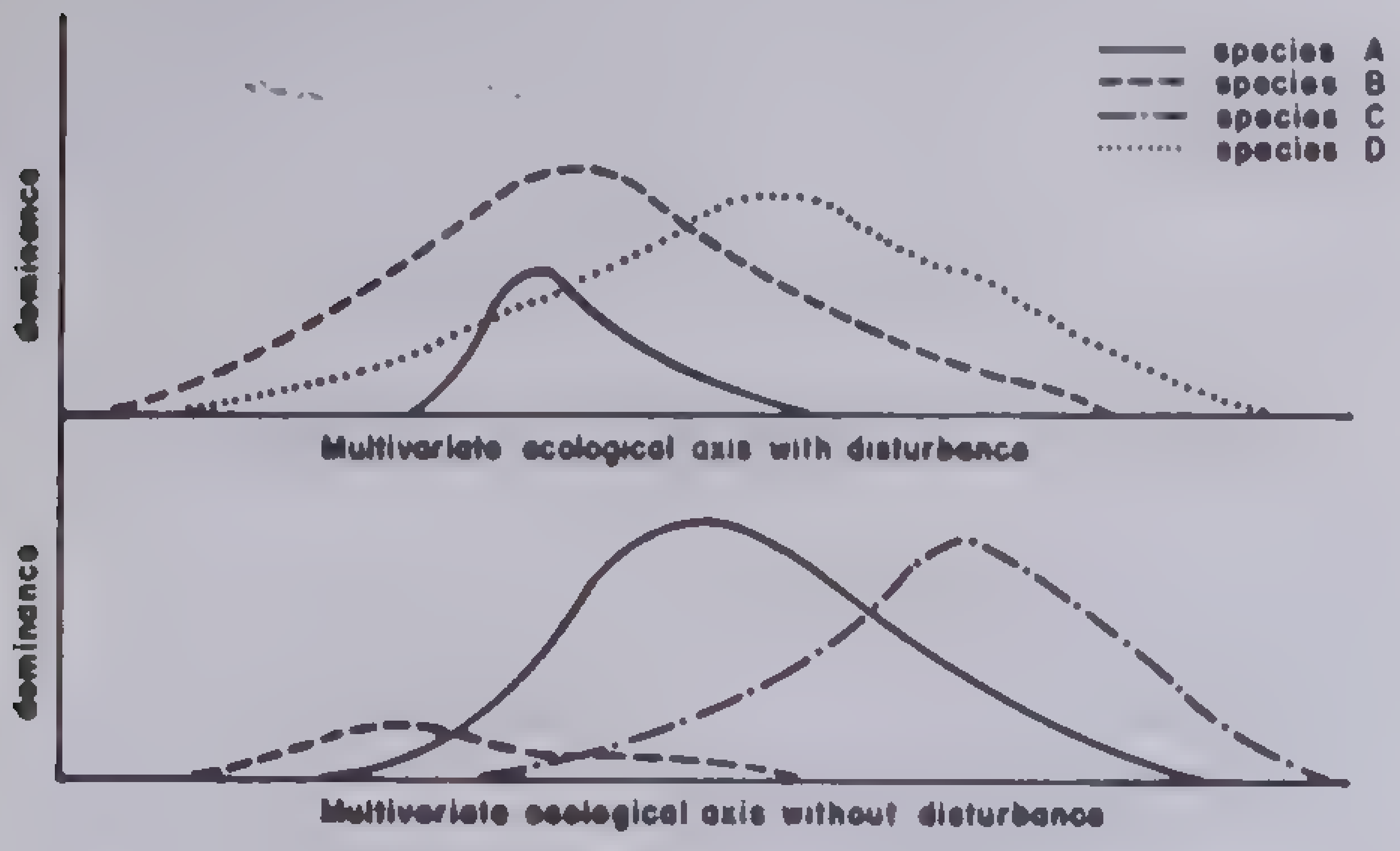

Figure 1--Comparison of species distributions with and without disturbance.

The upper part of figure 1 shows the added affect of disturbance in the distributions of these four species. Species A and B vary along the length of the axis in amounts and presence relative to the amount of disturbance. Species C can only exist without disturbance and species D can only exist with disturbance.

Gleason (1926) originally pointed out the importance of the individual species and their distribution in response to the ecological complex. The presence and amounts of species in plant communities and their shifts over time of stand development was theorized by Egler (1954) to be essentially independent. It is now apparent that various responses and interactions occur (Miles 1979). The same plant species will commonly not follow the same relationships at different points along the multivariate ecological axis. For example, one plant species may require shade of a dominant species in one type of environment, but not require shade in another type of environment.

The total environment that affects the group of plant species at any one point along the multivariate ecological axis and the interactions between those species is complex. Much of the variation in species presence and amounts often appears to be random, but as we identify the factors and interactions involved in plant response to the multivariate ecological axis it becomes apparent that much of this variation is predictable.

Stability and Climax

Plant species that occur in a stable or climax situation along the multivariate ecological axis are not in an environment that includes significant disturbance and they have had enough time to develop an equilibrium with their physical environment and plant interactions. Within a given community of stable or climax plant species, small areas may undergo short-term instability due to death of individuals, time of year affecting plant phenology, and effects of yearly climatic variation, but the overall plant community is stable (Daubenmire 1968).

There are five general characteristics of stable or climax combinations of plant populations (Daubenmire 1968; Mueller-Dombois and Ellenberg 1974; Hironaka and Fosberg 1979; Barbour et al. 1980). (1) The plant species are in equilibrium with the physical environment and normal levels of decomposers, parasitic pathogens, and herbivorous insects. (2) Interactions between plant species have reached an equilibrium although small fluctuations may occur. (3) There are no new species available from the flora of the geographic area that can establish and survive. (4) Competition between plant species is at a maximum. (5) The group of climax species forms the endpoint to stand development for a given site as long as the physical environment does not change, there are no introductions of exotic, competitive biota to the area, and there is not a genetic change in a plant population's ability to compete and survive.

The group of plant species that are present in a stable or climax state on any point of the multivariate ecological axis is a function of the climate, relief, parent material, time of soil development, and the potential biota of the geographic area (Jenny 1958; Major 1951). For this same point along the axis, the soil has codeveloped as a function of the same factors. Any permanent change in climate, relief, parent material, or potential biota will change the presence or amounts of stable or climax plant species and the soil. Over a geologic time period, the soil and stable or climax plant species will change as they codevelop and shift with changes in climate, relief, parent material, and/or additions or deletions in plant species.

Considering our time frame of study for what is considered stable and climax, the factors within a geographic area of primary importance that determine the combination of climax species that have potential to occur on any given site include landform, soil characteristics, climate, elevation, aspect, slope, and stable natural biotic factors. Correlation of the factors associated with the potential species complex can be used to determine the vegetation-site relationships.

Various general types of stable or climax groups of plant species occur depending on the complex of factors. On undisturbed sites where all plant species are native, it is considered to be a climatic or topo-edaphic climax, depending on its physical environment (Tansley 1935; Daubenmire 1968; Mueller-Dombois and Ellenberg 1974; Barbour et al. 1980). There are also disclimaxes (Daubenmire 1968; Barbour et al. 1980) or stable-state (Hall 1980) groups of plant species that cannot develop to equilibrium of native plant species with their physical environment, due to some factor. This may include those sites where (1) periodic fires of generally the same frequency, intensity, and timing restrict development, known as a pyric disclimax; (2) periodic, but natural herbivory restricts development, known as a zootic disclimax, or (3) introduction of an exotic plant species, typically without their native vigor-reducing insect and pathogen parasites, that are more competitive than the native climax species changes the species complex, known as a biotic climax.

During primary succession the vegetation, if undisturbed, and soil codevelop over time on a parent material as influenced by relief, climate, and the total biota (Jenny 1958, Major 1951). Some primary successions develop relatively fast, such as soil and vegetation development on newly deposited alluvial material (White 1979). Other primary successions involve relatively slow change of soil and vegetation, such as response to long-term changes in climate. It is important to realize that any change in the primary factors affecting vegetation and soil development create primary succession. As long as the vegetation is in equilibrium with its physical environment, it is climax or stable and a change in parent material, relief, climate, potential biota, or time will change the site potential whether it be relatively rapid change or slow change.

The change in climax or stable vegetation and its soil in response to these factors is often not in the direction of a more complex or further developed system. Erosion, either natural or caused by the impacts of man and resource use, can reduce the capacity of a soil to support the pre-erosion potential climax or stable community. A new climax or stable community will develop over time. Similar situations occur in response to land reclamation activities. Introduction of an exotic species, such as cheatgrass (Bromus tectorum) or leafy spurge (Euphorbia esula) may create a shift in the potential climax or stable community for a site. Removal of the reproductive source of native climax species through long-term intensive, selective grazing can change the potential climax or stable community. It is important that we understand the difference between changes that shift the potential of a site and disturbances that shift the vegetation on a site. Severe erosion or a flood can change the potential of a site from that supporting a tree-dominated potential climax or stable community to one supporting an herbaceous-dominated potential climax or stable community. In contrast, a stand-destroying fire, insect infestation, or logging can change the same tree-dominated climax or stable community to an herbaceous-dominated community, but it will not be in equilibrium with its physical environment and the potential climax community has not been changed.

Secondary Succession and Stand Development

All the plant species that are present at any given site are characteristics of the plant community. A plant community occupies an area that has boundaries and is composed of a combination of plant species (Mueller-Dombois and Ellenberg 1974). This definition does not restrict the size or variability of species presence or amounts. An area as small as a square meter supporting an aggregate of bryophyte and herbaceous species is a plant community just as the aggregate of plant species covering North America is a plant community.

Succession as defined by Daubenmire (1968) is the complete or partial replacement of one plant community by another. Secondary succession occurs when the community is not climax or stable and the site potential has not been changed by (1) soil development over time, (2) change in the factors climate, relief, parent material, and/or plant biota available to the site, or (3) site degradation due to soil loss or excessive accumulation (Mueller-Dombois and Ellenberg 1974; Miles 1979). Any change that does affect site potential is essentially a change in the primary successional development of the site and its potential climax or stable vegetation.

Secondary succession of plant communities in the direction of the potential climax or stable community for the site is progressive succession (Mueller-Dombois and Ellenberg 1974). Succession away from the climax or stable community is retrogressive succession, also known as retrogression. The climax or stable community is essentially the endpoint of progressive secondary succession (Miles 1979). This community is in equilibrium with its environment, while seral communities are not in equilibrium due to the added factor of a disturbance which opens sites for species not part of the climax or stable community, removes some species, and changes the competitive relationship between species.

A stand is a plant community with uniform physiognomy (gross appearance, structure and number of layers) that has relatively uniform species floristics (species presence) and species composition (amount of each species present) (Daubenmire 1968). Stand development is the change in the characteristics of the stand as it develops toward the climax or stable plant community for the site. It is important to realize that succession and stand development are not the same if the standard definition of succession is used. Succession, using the standard definition, involves a change in communities which means a change in the species present. Stand development may be a change in the species complex, but it also may be only a change in physiognomy, age, and/or amounts of species. In many cases after a disturbance, the resulting stand will have the same species as the climax or stable community, but the amounts of species, size, and age will be different. This stand is not in equilibrium with its environment and will mature and develop through a series of stands with different amounts, ages, and structures to climax or stability over time, but the species floristics may never change.

Miles (1979) has defined succession toward climax or stability as essentially stand development, including both changes in species floristics and composition. This may be more realistic, since the climax or stable community should be a different community from a seral, developing community, even though both have the same species lists.

Disturbances that initiate or shift the pathway of secondary succession or stand development may completely remove the existing vegetation, may selectively remove some species, or may only shift composition and structure. These disturbances include fire, windstorm, snow avalanches, ice storms, floods, cryogenic soil movement, drought, freezing, grazing, rodents, insects, plant diseases, logging, abandoned fields, and mechanical

manipulations by man (Daubenmire 1968, Heady 1973, Miles 1979, White 1979). Following a disturbance, the reactions between species already present or that immigrate determine the changes in the community (Muller 1969, Miles 1979). Reactions include any change in the habitat of one species by another species.

Following the impact of a certain type of disturbance or combination of disturbances there is a resulting stand. Over time, if disturbance is recorded, this stand develops toward climax or stability. It is important to understand that in most cases there is a continual variation of disturbances. For instance, we may burn a seral sagebrush/bluebunch wheatgrass stand that has had a certain amount of disturbance from grazing prior to the fire. Following the fire, a stand of lupine (Lupinus sericeus)/bluebunch wheatgrass develops and due to increased palatability, it is heavily grazed by both cattle and wildlife and is shifted to a western needlegrass (Stipa occidentalis)/geranium (Geranium viscossimum) dominated stand. As different disturbances, whether they be stand removing or species selective, impact the stand, a multitude of various types of stands and pathways away or towards stability (climax) are created. The stand composition is also influenced by reactions between species in their development toward or away from equilibrium with the site.

The effects of timing and intensity of disturbance are as important in determing eventual stand composition and development as the types of disturbance. Timing relates to the effect of the disturbance on the species during a phenological period, while intensity generally relates to the amount of removal.

The additional factor of frequency of a disturbance at a general time and intensity is important. Periodic fire can maintain the community and its development within a relatively narrow range of species and composition. Impacts of grazing at yearly intervals can maintain or shift species and composition in a community. The total combination of types, timing, and intensities of disturbances at various frequencies, coupled with available seed source and stand development, yield the variability in plant communities that can be observed for sites with the same potential.

Various hypotheses for pathways of succession have been developed. The initial concept of relay or facilitation floristics was developed by Clements (1916). Succession based on this concept is a directional single path change of communities toward the climax or stable community, with each successive community establishing itself because the preceding community had modified the environment in a favorable way. A very different hypothesis was developed by Egler (1954) based on the individualistic concept of Gleason (1926). This is the initial floristics or tolerance concept of succession. The initial vegetation and subsequent development depends on species that are present and immigrate and their different rates of growth, reproduction, and survival which results in variable replacement sequences that develop to the climax or stable community for the site. Connell and Slatyer (1977) developed the inhibition concept of succession. This hypothesis accounts for those communities that can exist at any point during succession and inhibit further succession for an indefinite period by physical occupancy of the site, monopolization of light, moisture, or nutrients, or production of allelopathic substances. It is apparent that all of these concepts operate in succession, often within one successional path (Connell and Slatyer 1977, Miles 1979, Huschle and Hironaka 1980). Succession on any one site is multiple path depending on the disturbance, species available to the site, and species interactions.

Huschle and Hironaka (1980) have developed the cone model which is a multiple path concept that includes all types of successional development. Each climax plant community for a site has multiple associated seral communities. A seral community will develop toward the climax in a pathway that depends on probabilities of various community characteristics and interactions. The cone is illustrated in figure 2.

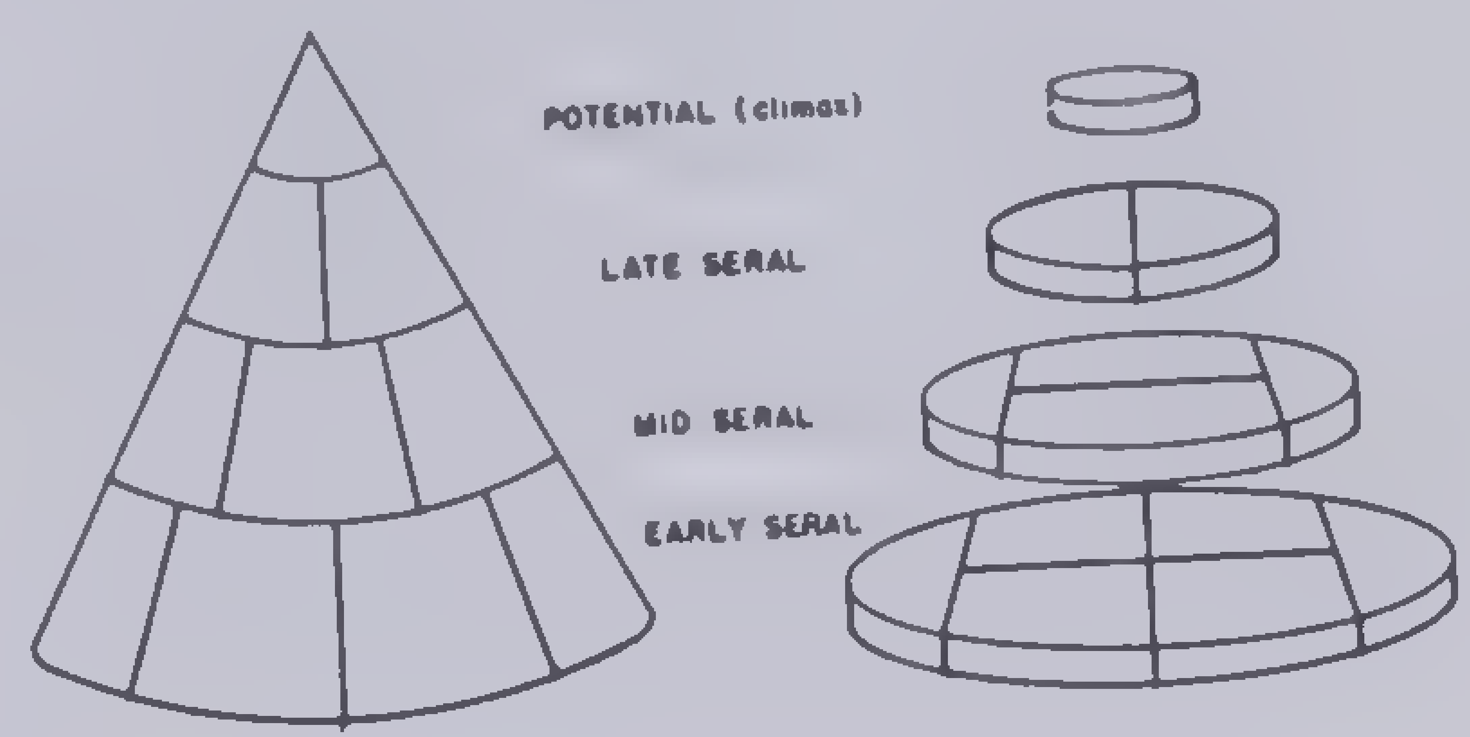

Figure 2.--Cone model with climax or stable community at the top and various seral communities and pathways of development in the cone (Huschle and Hironaka 1980). Each point in the cone represents a community.

Seral communities associated with different climax communities can be the same. For example a rubber rabbitbrush (Chrysothamnus nauseosus)/cheatgrass community can occur on both a site with a big sagebrush/Idaho fescue potential climax community and a site with an Idaho fescue/bluebunch wheatgrass potential climax community. Consequently, the cones for two different climax communites can overlap (Huschle and Hironaka 1980). This is illustrated in figure 3.

The cone is multidimensional and can contain an infinite number of communities. Generally the pathway of succession will be toward climax with varying probabilities for a particular pathway to climax. This model is very useful in developing predictions of seral pathways and for categorizing the total variation of seral communities associated with the climax or stable community for a site.

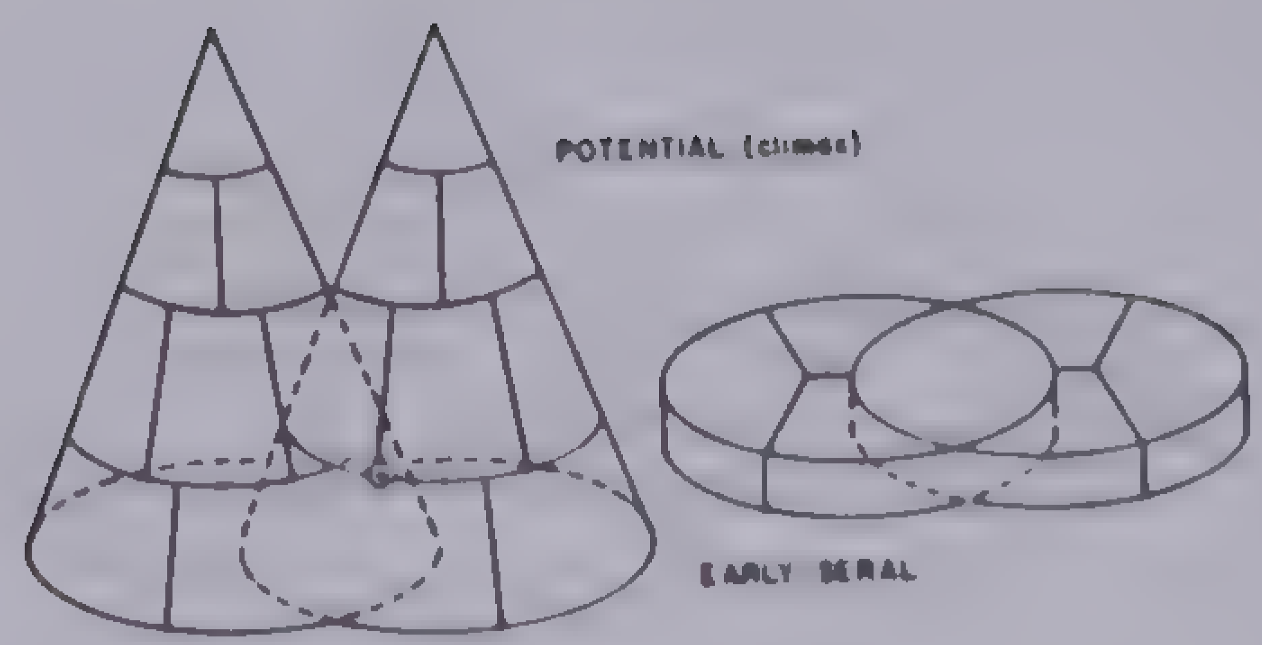

Figure 3.--Cone models that overlap such that they have common seral communities for different climax or stable communities (Huschle and Hironaka 1980).

Classification of the Land and Vegetation

Classification is the grouping of similar objects into groups (Bailey, Pfister, and Henderson 1978; Nelson, Harris, and Hamilton 1978). The method of classification is the taxonomy. A class in the classification is used alone or in combination with other classes as the descriptive basis for a mapping unit or to stratify variability for sampling. Each class has some predictable characteristics and some that are random. Various analytical methods can be used to develop predictions of relationships and attributes within classes or between classes.

A land classification groups similar physical environments by including different levels of variability of soil, landform, and climate. There are many different methods of classifying land. Excellent review of these methods has been done by Poulton and Tisdale (1961), Shiflet (1973), Mueller-Dombois and Ellenberg (1974), Bailey, Pfister and Henderson (1978), Cowardin (1978), Bailey (1980), Pfister and Arno (1980), Daubenmire (1980), Driscoll (1980), and Driscoll et al. (1982). In the Northern Region, a combination of the habitat type land classification system (Daubenmire 1952) and the landtype land classification system (Northern Region Soils staff 1976) is used to identify and develop mapping units for mapping, inventory, and development of predictions and management implications.

The habitat type is "all the land area capable of supporting one plant association" (Daubenmire 1968). This can be further defined as all the land units or sites that have the potential to support one type of climax or stable plant community. The land units or sites can be described and grouped based on similarity of soil profile, parent material, aspect, slope, climate, and position in the landscape. These land units or sites, if not disturbed, will eventually produce a similar climax or stable community, but usually support various seral plant communities in different states of succession.

A community type is a collection of similar vegetation stands. The stand is a plant community with uniform structure and relatively homogeneous species floristics and composition. When enough similar stands are studied, typical dominant, diagnostic (indicator), and characteristic species have value as predictors of ecological characteristics or relationships. A common classification of vegetation is the dominance type, also known as the vegetation aspect or cover type, and includes all stands with the same dominant plant species. The community type is grouped on a more ecological basis and is defined as all the stands in which the dominant and/or diagnostic species, or one or more of an ecological group of species, of corresponding layers are the same. In the warm, moist environments, and for disturbed vegetation, the variability is often large enough in species presence that groups of species tend to have the same ecological significance and the presence of one of a group of species has indicator value.

The climax or stable community type, which is the same as the plant association, is the type of community that is the endpoint of secondary succession (Hironaka and Fosberg 1979, Miles 1979, Barbour et al. 1980). This climax or stable community type may include native climax communities, stable disclimax communities, or exotic communities that indicate a new climax. Because of the broad amplitude of climax or stable plant species and the factor of compensating plant environments, climax or stable community types often include fairly broad site variability. Since plant species that occur in seral or disturbed communities often have narrower amplitudes and respond differently on different sites, there is often a broad variability in response of vegetation to treatment on one habitat type.

In order to reduce the variation in site characteristics within one habitat type, site types can be classified. A site type includes all of the sites within a habitat type that have similar soil, aspect, slope, climate, and place in the landscape such that (1) community floristics and species composition, (2) productivity of the community, and (3) soil surface characteristics respond similarly to treatment (disturbance) and stand development or succession over time. Within one habitat type, for a given geographic area, there is typically three to five site types. Where the climax or stable community type cannot be identified, site types can be developed based on similar site characteristics. Seral stands can then be grouped by site type, aligned in order of hypothetical stand development, and the climax or stable community type can often be predicted.

Seral community types are developed in a process similar to that of climax community types, except that more variability in community floristics and species composition, structure, and productivity usually must be accepted to group stands without developing an excessive number of classes. Seral community types can be aligned in stand development and successional pathways and relationships as discussed by Huschle and Hironaka (1980) and Hann (1982) as shown in figures 2 and 3. Predictions of change from one type to another in terms of probability, and time, along with community type attributes and management implications, can be developed with intensive study.

When classifying community types, whether they be climax or seral, it is important to realize that the divisions between classes are somewhat arbitrary and vary dependent on the amount and number of diagnostic or dominant species selected as key attributes for the classification. Figure 4 shows a simplified group of species and their change in presence or dominance in relation to the multivariate ecological axis. Each point along the axis is one stand or combination of species. The axis can be variables of site change or disturbance and stand development. If species A is selected as diagnostic, wherever it occurs in any amount, then there is only one class. If the classification is based on dominance of two species, then there will be seven classes: A/F, A/C, A/B, B/A, B/D, D/B, and D/E. When species C and D are used as diagnostic species, the types C, C/D, and D are formed. The more species that are used to identify a class, the more classes there will be. A classification could be developed that would almost put each point along the axis into its own class.

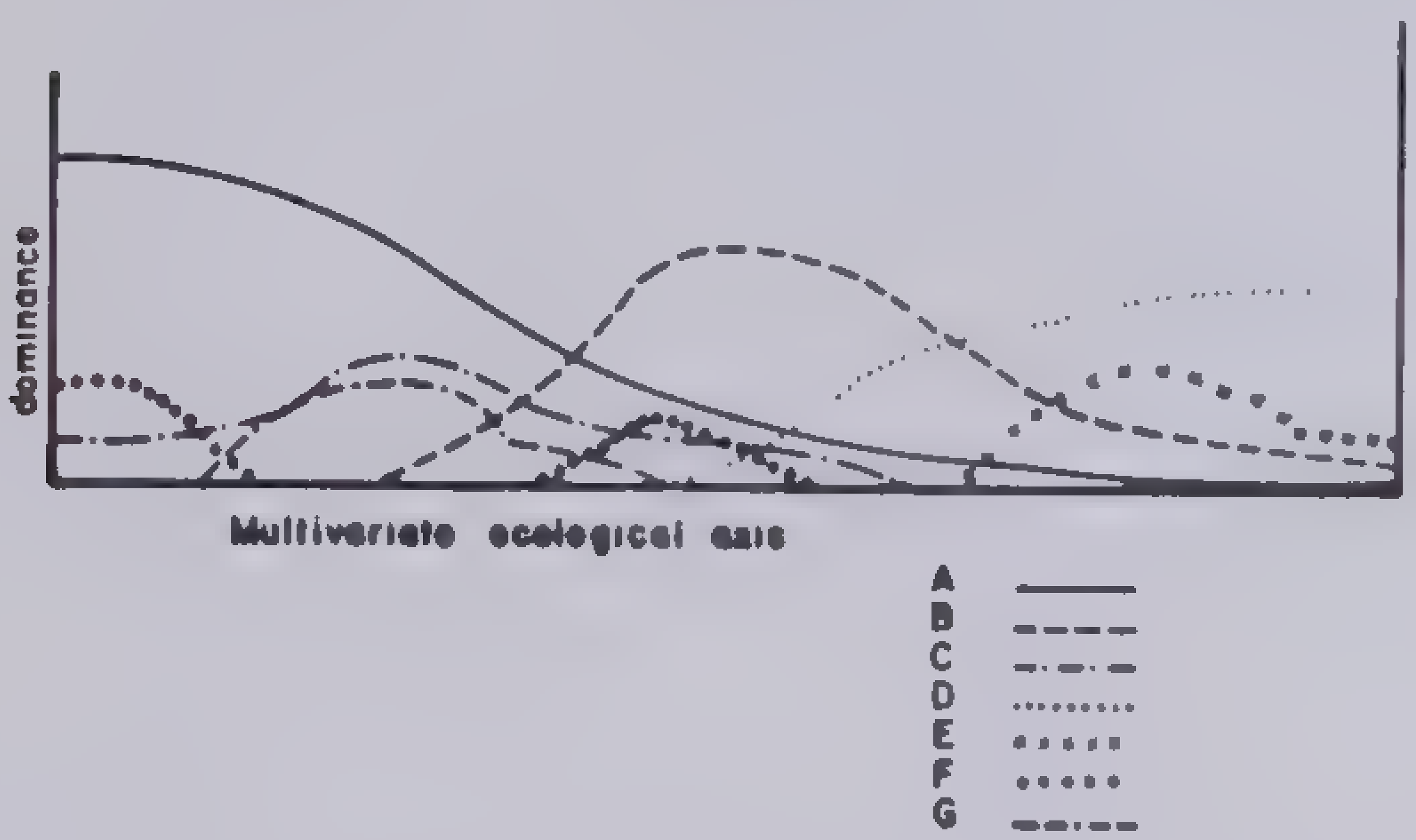

Figure 4.--Relationship of species presence and amount to change in site or disturbance variables and effect of species selection on class size. Each point along the axis is equivalent to one stand or combination of species.

The investigator developing a classification must use considerable caution in analyzing data both in terms of objective quantitative analysis and subjective evaluation. Testing of a classification is also very important.

The implementation of the land and vegetation classification (seral community type, by site type, within a habitat type) is the most important part of the system. Without implementation, the classification systems and their relationships have no purpose. Implementation includes use of the system for (1) developing mapping units; (2) inventory; (3) predictions; (4) management implications; and (5) an overall information system for use in storing and retrieving information on site and vegetation response to management systems, treatment, and changes in environment.

STATUS IN THE NORTHERN REGION

Much of the Northern Region has habitat type classifications that have been developed, refined, and tested. The classification of coniferous forest habitat types in northern Idaho (Daubenmire 1952, Daubenmire and Daubenmire 1968) has been developed and tested over a 30-year period. It was further refined for the Nezperce National Forest in 1976 (Steele et al.) and is now being refined for all of northern Idaho (Cooper et al. 1983). These systems have been very useful for operational resource management and have been integrated into standard management evaluations and predictions by foresters, silviculturists, wildlife biologists, range conservationists, soil scientists, and other resource management groups. There is little doubt that the concept of the habitat type developed by Daubenmire (1952) is a realistic and applicable concept. Further development of management implications concerning habitat type-site descriptions and seral community attributes and relationships make the overall system even more valuable.

Pfister et al. (1977) has classified the coniferous forest habitat types of Montana. The classification has been tested, is being used on an operational basis, and is an excellent system. As higher resolution is required for management predictions and evaluations, some refinement may be needed on individual National Forests.

Grass and shrub steppe habitat types of western Montana have been classified by Mueggler and Stewart (1980). The classification has been tested and is presently being integrated into operational management in terms of a stratification system for determining ecological and resource conditions ratings of existing vegetation and for predicting rehabilitation potentials. In the future it may be refined to account for site differences indicated by the big sagebrush (Artemisia tridentata) subspecies and to improve resolution by National Forest.

Grass- and shrub-steppe habitat types of northern Idaho have been partially classified. Daubenmire developed an initial classification of associations as early as 1942 and classified the habitat types of eastern Washington in 1970, which applies partially to northern Idaho. Tisdale (1979) has developed a preliminary habitat type classification for the grasslands of the Snake River Canyon. The Northern Region Ecological Services Group is planning to initiate a reconnaissance of these types in 1983, integrate what has already been done, and develop a complete classification over the next several years.

The habitat types of southeastern Montana and northwestern South Dakota, and for North Dakota are being developed by Hansen and Hoffman of the University of South Dakota and Goetz, Barker, and Girard of North Dakota State University. These classifications are in the initial stage of development and have not yet been tested for operational use.

Riparian and wetland habitat types dominated by deciduous trees, shrubs, and herbaceous species have not been classified in northern Idaho or western Montana except for a small area on the Lolo National Forest (Hann 1982b). Classification of these habitat types is scheduled as an objective for the Northern Region Ecological Services Group.

Alpine habitat types for northern Idaho and Montana have not been classified. Classification of these habitat types is scheduled as an objective for the Northern Region Ecological Services Group. A reconnaissance and preliminary classification of a small part of the Absaroka-Beartooth area in south central Montana is scheduled for 1983 and 1984.

Development of habitat type-site descriptions and stratification of habitat types into units with uniform environments is considered an important need in the Northern Region. Some of this work has been initiated on a test basis with combined efforts of soil scientists and plant ecologists.

There has been considerable successional pathway description, stand development analysis, and pretreatment-posttreatment prediction development in the Northern Region. However, this type of information has not been summarized to any extent on a community type classification basis for all existing vegetation by habitat type. Arno and Zimmerman (1982) classified community types and analyzed successional relationships for four forest habitat types in west-central Montana. Hann (1982) classified community types and analyzed successional relationships in one forest habitat type and one grassland habitat type on a portion of the Deerlodge National Forest in west-central Montana. Stewart (1981) analyzed successional development and communities related to time from herbicide treatment in one sagebrush habitat type in southwestern Montana. Huschle and Hironaka (1980) classified community types and analyzed successional relationships for grassland habitat types of the Snake River Canyon. The continued development of community type classifications and successional relationships by habitat type is considered an important objective for the Ecological Services Group, along with evaluation of related treatment effects.

SUMMARY

Classification of grass and shrub steppe ecosystems in the Northern Region is a combination of a land classification system based on the sites with similar potential climax or stable vegetation, and a vegetation classification system based on similarity of plant communities. The land classification system is the habitat type concept developed by Daubenmire (1952). The vegetation classification is a system that is based on community types which are groups of stands with similar floristics and species composition. Various community types, that result from an array of disturbance or treatments and subsequent stand development pathways, can be classified for a site type within each habitat type.

The individual species and its response to various environments, treatment or disturbance, and competitive interactions during stand development is the attribute that must be studied to understand community relationships. Although the community type consists of stands with similar floristics and species composition, two to three diagnostic species are usually used to identify a community type. These diagnostic species should be consistent in their response to the primary variables affecting the type of community that is present.

The overall system which includes an array of community types that occur in response to various disturbances and multiple pathway successions for each site type of a habitat type, is useful in inventory stratification, synthesis of management implications, treatment response predictions, and information storage and retrieval. Each community type has an ecological condition, which is its distance from the climax or stable community type for that site, and various resource value conditions, such as for cattle, sheep, or elk production. Once the classification system has been developed and the resource values determined by community type, then a manager can key out a stand using the community type key and descriptions, and without any further analysis, know the ecological and resource value conditions along with other valuable information. This system has been tested and is being put into use in the Northern Region. It is a system that will work not only in the upland grass and steppe habitat types, but also for forest, riparian and wetland, and alpine habitat types.

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Comparison of Habitat Type Classification to Some Other Classification Methods[1]

V. Komarkova[2]

Abstract.--Vegetation should be described first in terms of floristic relationships which can be determined objectively and the system of successional relationships should be superimposed on the floristic system later. Subjective location of floristically and environmentally uniform stands is the most efficient method of sampling site selection for large-scale vegetation surveys. Usually, samples of individual habitat types should not be repeated at the expense of sampling of the diversity of communities in the study area. Plot size and shape may be fitted to the expanse of the homogeneous stand. List of all taxa present in the plot is the most important sampling objective; semi-quantitative estimates of the importance of each taxon and of the environmental variables are sufficient for large-scale surveys. Raw stand data should always be published. Traditional and numerical classification and ordination techniques are complementary. A uniform system of habitat type names derived in a standard way is essential for record keeping and communication. Higher units grouping habitat types should be derived by the same methods as habitat types.

INTRODUCTION

Successful land management needs a land unit classification system and inventory, an areal map of the land units, and an understanding of the dynamics of the units to determine the response of the units to management practices and other human and natural disturbances. This response may be arrived at by modeling or by other methods, and it should vary as little as possible within each classification unit (Franklin et al. 1970, Pfister 1973, Franklin 1979, Kessell 1979a). Permanent plots may be established in classified land units for long-term observations (Franklin et al. 1970); such observations are particularly important in areas of rapid change.

Large-scale resource inventories which have to be carried out in a relatively short time and within a limited budget have to use efficient, rapid techniques of data collection and analysis which, under these constraints, produce the greatest amount of useful information (cf. Franklin et al. 1970, Moir and Ludwig 1979). The best sampling method will be both accurate and precise; "accuracy" is close agreement of sample means with parameter means, while "precision" is close agreement of sample means to each other, without reference to the true mean (Barbour et al. 1980). In large-scale surveys, some precision and accuracy have to be traded off for savings in time and cost. How is the trade-off determined?

The efficiency of a method may be judged by its power to return a maximum understanding of the structural complexity of vegetation and of its relationship to environmental factors for a minimum of time input (Lambert and Dale 1964, Moore et al. 1970); Lindsey (1956), Lindsey et al. (1958), and others timed the sampling times for comparison. Kessell (1979a, 1979b) emphasized the importance of the degree of resolution, which is needed for the specific management goals, for the method selection.

The habitat type approach was developed by R.F. Daubenmire (1952) for classification of forest ecosystems and lands in northern Idaho and eastern Washington. It has been used in a number of regions of the western United States and it provides a basis for

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comparison between these regions and the continuity of data and results (Layser 1974, Pfister 1976, Pfister and Arno 1980 and Pfister 1981). Pfister and Arno (1980) put together a sampling approach which uses the minimum quantitative data necessary for classification of habitat types; they based their methods on R.F. Daubenmire and J.B. Daubenmire (1968), Franklin et al. (1970), their own experience, and partly on Mueller-Dombois and Ellenberg (1974). Despite efforts to keep the method consistent, there is still considerable variation in sampling procedures and terminology which needs to be clarified and a need to improve efficiency and reliability of techniques (Pfister and Arno 1980). The variability is, in part, caused by the need to vary the method with the natural features of each specific area (Franklin et al. 1970). This paper compares the habitat type approach to other classification methods.

HABITAT TYPE APPROACH

According to Wasser and Hess (1982), "a habitat type represents the aggregate of all areas that support, or can support, the same primary climax (potential natural) vegetation and which delineate an environment of distinctive potentialities including pristine and derived types of communities." While habitat type theoretically represents an ecosystem unit, the habitat type classification system is now based on a vegetation classification system and can thus be compared with other vegetation classification systems. As R.F. Daubenmire (1968) and Franklin et al. (1970) pointed out, vegetation is the best integrator of habitat factors and indicator of ecosystem units in a landscape; floristic differences always reflect environmental differences.

The habitat type system is parallel to other subjective ecosystem classifications developed, for example, by Ellenberg (1973) and Walter (1976) and Walter and Box (1976), and to the systems of biogeocoenoses (Sukachev 1945) and biogeoclimatic units (Krajina 1965, 1969); these systems are also based on vegetation classification. Objective classification of ecosystems has not yet been developed as it would have to be based on quantitative data for all ecosystem components. A start was the work of Driscoll et al. (1983) which dealt with four main ecosystem components including vegetation, soils, water and landforms; however, this system was not designed to be integrated.

In the Daubenmire's classification system, each "climax", mature, undisturbed association represents a different habitat type and a unique set of environmental conditions. Each phase represents a habitat type subdivision; phases are recognized as more substantiation for the association becomes available, and often replace each other in different geographical areas. "Successional" communities (communities recovering after disturbance) are assigned to the "climax" (potential natural) associations into which they presumably develop.

In my view, this limitation of the term "association" to "climax" communities is incorrect. According to Flahault and Schröter (1910, Third International Botanical Congress in Brussels), the definition of an association is the following: "An association is a plant community of definite floristic composition, presenting a uniform physiognomy, and growing in uniform habitat conditions." Meijer Drees (1951) defined the association as "a plant community identified by its characteristic taxon combination, including one or more (local) character-taxa or differentiating taxa." This definition, which was based on that of Braun-Blanquet (1921), was endorsed by the symposia of the International Society for Vegetation Science and by the Sixth Botanical Congress at Amsterdam, 1935 (Westhoff and van der Maarel 1978). An association defined in this way is a fundamental unit of vegetation classification (Westhoff and van der Maarel, 1978); in the description of vegetation, association has a role analogous to the role of species in the description of organisms. This definition of association can be extended to many distinct recovering communities which repeatedly occur in parallel recovering environments which they may occupy for a long time. These communities are not included in Daubenmire's system as separate units. Flahault's and Schröter's associations can be equated with Daubenmire's associations in all other respects, and a subassociation can be equated with a phase.

The first step in the present process of definition of habitat types is an objective derivation of vegetation units which are later fitted with soil descriptions and characterized by their range on a variety of environmental gradients. However, it is very difficult and sometimes impossible to describe a number of environmental factors including disturbances quantitatively (e.g. Pfister 1981), and quantitative evaluation of most other environmental factors may be very time consuming or impractical (such as a comparison of temperature regimes of individual plots for which measurements would have to be carried out simultaneously). The disturbance factors provide for less than optimal environment; they include, for example, animal and human activities, fires, prolonged duration of snowcover, large amount of moisture, or substrate movement. An expedient way to deal with this problem is to sample and partially analyze the soils, and to estimate the influence of other factors on subjective scales which reflect the width of the gradients from the lowest to the highest factor levels. The values can be estimated between scale points 0 and 5 or 0 and 10 (absence vs. a high factor level; e.g. Loucks 1962).

The need for rapid determination of selected environmental factors was also emphasized by Franklin et al. (1970) who

concluded that their community types represented relatively homogeneous environments. The degree of uniformity of communities undisturbed by humans and the degree of uniformity of their habitats correspond (Komarkova 1980) ; and the recovery of the original plant communities and the degree recovery of their habitats appear to correspond (Komarkova 1983). As our knowledge of habitat types, their environment and dynamics increases, it will be possible to involve more objective environmental information in the derivation of the habitat types and in their description. Gradually, they will objectively approach the ecosystem units (i.e. ecological types or ecological response units).

VEGETATION AND DISTURBANCE

After an initial, usually exogenous disturbance, a relatively rapid, short-term period of community response takes place. This process of "succession" operates like a control system, driving populations and related variables toward environmentally determined limits which physically cannot be exceeded (Gutierrez and Fey 1980), i.e. toward the beginning of the following "climax" period during which the now mature community undergoes long-term changes at a slow rate. This slow community change is controlled by low intensity, slow disturbances, either exogenous (e.g. climatic change) or endogenous, and it includes both small cyclical variations and slow directional changes.

Because of its controversial nature (e.g. Mueller-Dombois and Ellenberg 1974), it may be better not to use the term "climax" at all (Walter 1937, Egler 1947, Mueller-Dombois 1974), or to use it only with a clarifying definition (Whittaker 1953). The term "potential natural vegetation" has the advantage over the term "climax" of no implications as to the length of duration of vegetation in the landscape. Both the concept and the term "potential natural vegetation" were developed by Tüxen (1956, 1957) during his studies of cultural landscape in Northern Germany where vegetation has been profoundly modified by landscape changes and by man's long-term activities. He defined "potential natural vegetation" as the vegetation that would develop if all successional sequences were completed without interference of man under the present climatic and edaphic conditions, including those created by man (Mueller-Dombois and Ellenberg 1974). This concept was also interpreted by Küchler (1964, 1973).

The term "potential" should be limited to vegetation potential for sites undergoing recovery because it does not apply to mature, complex vegetation which has not been disturbed by humans, i.e. to natural vegetation. "Natural" should not be confused with "original", i.e. with vegetation that was present in an area before man had any influence on it and perhaps under different climatic conditions (Mueller-Dombois and Ellenberg 1974, Westhoff and van der Maarel 1978). "Undisturbed" vegetation is not a satisfactory term as probably all vegetation has been disturbed at one time or another, and terms "mature" and "complex" are not specific enough.

According to Mueller-Dombois and Ellenberg (1974), when referring to broad zones of natural vegetations, it seems advisable to use instead the term "climax" the terms "zonal", "azonal", and "extrazonal" or "intrazonal". These terms were developed in Russian geobotany (see Walter 1943, 1954, 1964); they have geographic, not temporal implications and relate exclusively to the natural plant cover. A "zonal" community corresponds, more or less, to a climatic climax and an "azonal" community to an edaphic climax, controlled primarily by extreme soil conditions; azonal communities with very similar composition may occur in neighboring vegetation zones. Extrazonal units reach, for example, into the neighboring cooler zone on warmer south slopes. The term "intrazonal" refers to vegetation units that are found only in one vegetation zone where they occur in locally unique habitats.

Partial disturbances probably affected most of vegetation in the past, and one-time, severe disturbances are widespread. At any one time in most regions, most stands and communities are recovering from disturbance and only very few are mature, persisting, complex, developed in the absence of disturbance, and perpetuate themselves through reproduction ("climax"); this was pointed out, for example, by R. F. Daubenmire (1980). In ecosystems such as the alpine, where some areas were little disturbed by humans due to inaccessibility and little economic interest, the proportion of these communities is considerably higher than in heavily exploited ecosystems such as forests.

While they usually lack the complex structure of mature communities, recovering communities are often floristically well-defined, persist for a long time, and may have a composition substantially different from the composition of the mature, undisturbed communities into which they may develop. For example, on the Alaskan Arctic Coastal Plain, the zonal communities are dominated by cottongrass tussocks, while communities recovering after surface disturbance in zonal habitats are dominated by grasses which occur in the zonal cottongrass communities only in small amounts. The relationship between these recovering and mature communities cannot be derived objectively by numerical analysis. Some of these recovering communities have consistent, persistent floristic composition within parts of the circumpolar Arctic. The recovery rates differ for different communities and ecosystems; on the same arctic human-disturbed site, recovering marshes were considerably more similar to undisturbed azonal marshes than the recovering uplands to undisturbed zonal uplands (Komarkova 1983).

In some geographical areas vegetation may be in various stages of recovery from disturbance and the "climax" communities may be entirely absent. Natural disturbances may have effects analogous to, for example, grazing which may completely obliterate natural communities and produce new communities with different composition which are maintained as long as the disturbance lasts. For instance, the vegetation on the Arctic Coastal Plain, Alaska, has more numerous vegetation types which are less well defined and more continuous than the vegetation in the Indian Peaks area, Colorado Rocky Mountains (in areas of comparable size and vascular plant diversity). This is probably due to both steeper environmental gradients in the Colorado alpine and to periodic disturbances of the arctic landscape by thaw lake cycle, rivers and wind in intervals of several thousand years (Komarkova 1982). Similar reasoning may perhaps be applied to forests frequently disturbed by fire or windthrow (e.g. Sprugel and Bormann 1981).

Communities recovering after disturbance often cover large areas. It may be difficult to assign them to a potential vegetation unit, particularly when all of the original vegetation has been removed or did not exist, when irreversible ecosystem changes took place during or as a consequence of disturbance, when recovery is so slow that climatic changes take place before the recovery is complete, or when the original vegetation was a relict of a previous climatic regime. In most such cases the recovery may lead to new vegetation types which do not exist at present. For example, a permanent shift in vegetation has been documented in central Europe where beech forests became established only after the last glaciation (Ellenberg 1974, Mueller-Dombois and Ellenberg 1974).

All these are arguments for description of vegetation units on the basis of existing vegetation. Because in many cases the successional relationships of a community cannot be determined, vegetation should be described first in terms of purely floristic relationships which can be determined objectively and the system of successional relationships should be superimposed on the floristic system later. The objectivity of the structure of successional relationships can be improved as more information on the related dynamics of recovering and "climax", floristically-based units becomes available.

According to Pfister and Arno (1980), inclusion of "mature" successional stands (i.e. stands in mid or late succession) as well as near-climax stands improved the efficiency of sampling because contrasting sites could be sampled as encountered in the field. The key and vegetation descriptions were also more representative of existing vegetation. In addition to "climax" stands, seral stands are important for the management as seral taxa are usually favored producers (Steele et al. 1981). Sampling of vegetation recovering after disturbance also clarifies the role of individual taxa in the recovery and identifies those which are limited to the recovery stages.

PLOT SELECTION

Plot selection is the key to a successful vegetation or habitat type survey. Ideally, an entire geographically limited universe (for example, a mountain range) characterized by relative environmental, biotic and historical distinctiveness and uniformity should be sampled (Komarkova 1980). Within each such universe, the entire community and taxa diversity should be sampled to determine the ecological range and optimum of each taxon and to determine which taxon is diagnostic for which vegetation unit. Because ecological ranges and optima of individual taxa may be different in different geographical regions due to varying environmental, including competition, conditions, vegetations of individual geographical regions cannot be compared as whole entities except on the basis of data for all the communities and taxa within each of the regions.

In practice, this is usually not possible because of budget and time constraints. Extreme examples of recovering, successional stands are usually the first to be excluded from the survey; while it is time-consuming to search for "climax" stands (Pfister and Arno 1980), more time is spent by sampling and processing both "climax" and successional stands. The determination of the "climax" stands has to be made prior to sampling. The method of selection of old mature stands by investigating historical sources, maps, aerial photographs, and by reconnaissance was described by Pfister and Arno (1980). According to R.F. Daubenmire (1970), a stand is considered "climax" if all young perennials that appear successful in the community are represented by old individuals in the same stand; alien taxa are absent or if present are represented by few individuals of low vigor; and fire-sensitive taxa native to the area are not conspicuously absent.

In forested vegetation, Daubenmire's associations are defined primarily on the basis of the relative reproductive success of trees which indicates which taxon will become the self-perpetuating dominant of the overstory; association subdivisions are based on the types of herbaceous and shrubby undergrowth (R.F. Daubenmire and J.B. Daubenmire 1968). If disturbance is only partial, the potential natural vegetation type can be suggested by indicator or diagnostic taxa remaining in the understory; clues may also be obtained from the neighboring undisturbed stands. Community composition, structure and a subjective evaluation of the roles of individual taxa are the criteria for assignment of recovering nonforested vegetation to Daubenmire's

associations.

While historical research contributes to the determination of "climax" stands, it is a necessity for correct interpretation of stands recovering after disturbance. The samples of recovering vegetation may be placed on sites of known disturbance age and history such as on abandoned railroads and roads, burns, landslides, or construction sites. Vegetation recovering on, for example, surface disturbances of the same age and belonging to different "climax" associations can then be compared. Retaking of historical photographs (e.g. Phillips 1963, Gruell 1980a, b) may be a significant aid in these studies.

For large-scale vegetation surveys with the objective to sample the complete range of natural communities and sites (Franklin et al. 1970), subjective selection of floristically and environmentally uniform stands is the most efficient method of determination of sampling sites; the homogeneity of all vegetation layers (judged on physiognomy, structure, and composition) and of the environment are the criteria. There is no satisfactory objective method for determining homogeneity (Mueller-Dombois and Ellenberg 1974), which is an analytic concept based on comparing a number of plots of the same size taken from an individual stand.

Franklin et al. (1970) emphasized the value of systematic sampling in areas where changes in communities are subtle. Both systematic and random sampling have been rejected, for example, by Pfister and Arno (1980) who argued that many vegetation types would be lost and many stands would be repetitive or heterogeneous. To sample an area adequately in a random or systematic way would increase the overall effort several times. Moore et al. (1970) concluded that finding of random points can be extremely time consuming, and that random sampling can lead to the omission of obvious vegetation and taxa; the plot selection should be subjective and cover all the main vegetation types except in areas where the vegetation is unknown and where the sampling should be quasi-random. In that case, stratified sampling according to a system of landforms or some other attribute of the abiotic environment may be of help. Stratification of vegetation samples on some ecosystem attribute other than vegetation is also statistically sounder (Orlóci 1978, Orlóci and Stanek 1979). Westhoff and van der Maarel (1978) wrote that to equitably represent the variation in vegetation and to avoid mixed, incomplete and unstable stands, a subjective, "stratified " sample selection is far superior to random sample choice. The sample also should not fall into an ecotone or an area transitional between habitat types. Pfister et al. (1977) interpreted ecotones as narrowly as possible; more of the area is then definable to habitat type and less is in ecotonal categories which may be impractical for use in resource management.

Ideally at least, several stands should be sampled for each vegetation/habitat type to cover its variability in environmentally different regions of the study area. When this is not possible, one stand is sufficient for description of a vegetation type (similarly as one organism is sufficient for description of a species; Barkman et al. 1976). If only one stand per habitat type is included, it has to be a very good representative stand rather than the first stand encountered during sampling. In large-scale surveys, samples of individual habitat types should not be repeated at the expense of the sampling of the diversity of communities in the study area. In general, the benefit in terms of increased knowledge of variability of each type is not outweighed by the loss of information on the successional status and the ecological range and optimum of individual taxa.

Considerably greater benefits are derived from repeated sampling of individual vegetation types than from repeated sampling of individual stands; Daubenmire's method requires sampling of 50 microplots in the forest understory of each 375-m^2 plot. Presence degree of a taxon in a vegetation type is measured by the number of samples in which the taxon occurs expressed as percentage of the total number of samples. If the plot samples are all of equal size then presence is the same as constancy. Frequency is the distribution of a taxon in subsamples of the total number of subsamples in a given stand (Westhoff and van der Maarel 1978).

There is no productive use for frequency data in large-scale and in medium-scale vegetation surveys. Presence degree or constancy data, on the other hand, describe the variability of each vegetation type and the distribution of each taxon within each vegetation type. The latter information is valuable for the designation of diagnostic or indicator taxa for vegetation types for regional comparisons between vegetation types, and for the derivation of the higher-level vegetation units of the classification system.

The inefficiency of highly repetitive sampling within stands was mentioned by Pfister and Arno (1980); estimating the undergrowth coverage for the entire plot rather than for 50 microplots within each plot increased two to four times the number of stands they were able to sample and allowed for greater coverage of communities. Moore et al. (1970) found that with a single worker, local frequency determination in 50 subquadrats required 2½ times as long as one large sample. Also Mueller-Dombois and Ellenberg (1974) emphasized the advantages of an investment of the effort in a greater number of samples than in accurate evaluation of cover in a part of a smaller number of samples such as the sampling of 20 microplots by Bliss (1963).

PLOT SIZE AND SHAPE

Sampling of plots of sizes fitted to the sampled communities rather than using plots of standard size results in considerable savings of field time and in higher-quality data.

Minimal area is the minimal surface which has to be occupied by a sample of a plant community if the normal specific assemblage will be able to develop (Westhoff and van der Maarel 1978). Tüxen (1970) found minimal areas which ranged from several dm^2 to more than one hectare. While Daubenmire's plot size (375 m^2) is useful in forest stands, smaller plot sizes are sufficient for scrub, herbaceous vegetation (5 to 100 m^2), and bryophyte-and lichen-dominated vegetation (0.1 to 4 m^2), according to the size of the dominant taxon (Mueller-Dombois and Ellenberg 1974). Pfister and Arno (1980) pointed out that plot size needs to be larger than 375 m^2 in sparse forest stands. Plots should not be smaller than the minimal area of the sampled community type because then taxa are underrepresented (Westhoff and van der Maarel 1978).

While it is useful to have plots of the same size and shape throughout a study area, inclusion of nonhomogeneous vegetation or of two or more communities in one sample to satisfy the plot size requirement introduces considerably greater error in the data than sampling of plots smaller than minimal area. For example, in alpine or arctic regions the size of landforms and of homogeneous community stands associated with them is usually very small and homogeneous stands 375 m^2 large do not occur in most communities. In the Alaskan Arctic, even 10-m^2, long rectangular plots introduced noticeable heterogeneity into the data set (unpublished data). Very large plots (e.g. Curtis 1955) are necessarily heterogeneous (Mueller-Dombois and Ellenberg 1974).

The shape of the plot makes little difference for the results of a large-scale vegetation survey as long as the plot covers the community taxa diversity and is limited to a homogeneous area. Square and round plots often encompass less heterogeneity than a long narrow plot (Clapham 1932, Bormann 1953).

In their ability to include only homogeneous vegetation in the sample, methods such as the Braun-Blanquet's, which do not designate size and shape of the plot and fashion it to the homogeneous area, have a distinct advantage over methods which use plots of standard size and shape. In case the latter methods are used, time may be saved by not marking the exact plot boundaries (Franklin et al. 1970).

PLOT SAMPLING

A rapid plot sampling technique results in considerable time savings.

The data collected for each plot or subplot usually consists of: (1) a record of all or the most important taxa present by the layer in which they grow and (2) an estimate or a measurement of the quantity of each taxon in the plot, such as its percentage cover, coverage class, or phytomass. Other taxa data which may be collected include abundance, sociability, height, frequency, stem diameter, vitality, fertility and phenology. Age/structure data is important for the determination of successional status of forested stands and tree taxa; the methods have been described by R.F. Daubenmire and J.B. Daubenmire (1968) and by Pfister and Arno (1980). Franklin et al. (1970) recorded abundance and coverage separately for reproduction and mature size classes of each tree taxon.

Most important of all is the record of all taxa present in the plot (also Pfister and Arno 1980) including, if possible, the bryophytes and lichens. Complete stand data are essential for the determination of ecological ranges and optima of taxa, determination of indicator or diagnostic taxa, variability within types, for regional comparisons of whole regions, and for geographical studies of individual vegetation types.

Any semiquantitative measure of importance of each taxon in each stand such as the coverage class (Daubenmire 1959, Pfister and Arno 1980) or percentage cover estimate is sufficient for large-scale vegetation surveys and for many other purposes (Mueller-Dombois and Ellenberg 1974). Because objective is to describe the spatial floristic variation of a regional vegetation cover, the emphasis is put on more samples with semiquantitative estimates rather than fewer samples with exact measurements of taxa quantities; measurements always require more time (Mueller-Dombois and Ellenberg 1974). In any case, vegetation properties are not normally amenable to exact determination and they have to be estimated via a limited sample (Orlóci 1978)Estimates may be occasionally calibrated by using more exact procedures (Franklin et al. 1970). The errors in subjective estimation may be caused by method errors in taxa which are difficult to observe, fluctuation in abundance between years, seasonal changes and heterogeneity (Hope-Simpson 1940). Because of a differential bias from one individual to another, it is unlikely that any estimates would agree closely (e.g. Schultz et al. 1961). Measurements are more appropriate than estimates for, for example, periodic reassessmet of permanent plots (Mueller-Dombois and Ellenberg 1974).

DATA MANAGEMENT

Field data have to be computerized in large-scale vegetation surveys which often have hundreds of samples. Preservation of these data for perpetuity and making them

available to other researchers is crucial. The only truly permanent record of raw data is their publication; all stand (vegetation and environmental) data should be published, best in tables included with the vegetation descriptions (e.g. Major 1981). Computerized, quality-assured data should be stored at regional data management centers where it would be available, for example, for regional analyses or new analyses of vegetation types for which more data became available. The need for data management systems which would handle the great number of vegetation samples now in existence (possibly in excess of 100,000) was emphasized by van der Maarel et al. (1976). A number of data management systems at various levels of sophistication are available (e.g. Lauff et al. 1983).

ANALYSIS

There is little difference in data analysis between the Daubenmire's and Braun-Blanquet approaches. Tabulation of data and rearrangement of tables to arrive at vegetation types and their indicator or diagnostic taxa groups are used in similar ways, and both approaches utilize numerical methods to analyze vegetation and environmental data sets (Franklin et al. 1970, Pfister and Arno 1980, van der Maarel 1981). Numerical methods can be applied to both stand data and to data for vegetation types at various hierarchy levels.

Classification and ordination techniques are complementary (van der Maarel 1969); their combined results are more informative than results of either technique alone. Numerical methods often improve on traditional classification and vice versa (Franklin et al. 1970). The results of tablework can facilitate the interpretation of numerical analysis, particularly the relationship between vegetation types and the factors of the abiotic environment (Komarkova 1980).

According to Goodall (1978), numerical classification has advantages over more traditional methods if it is quicker; it uses less skilled labor; it is more objective; it more consistently identifies and uses natural discontinuities; or it uses optimization procedures. While most of these advantages are realized, numerical classification methods usually are not quicker, particularly if the traditional table rearrangement is done by computer. Consistent and objective search for discontinuities is also not realized in most techniques; the theoretical advantages of numerical over traditional classification seem to be more in potential than in performance (Goodall 1978). The main disadvantage of dendrograms, which clearly display the similarity of samples, is that there is no criterion for choosing the best coefficient of similarity; different coefficients may produce different results (Moore et al. 1970).

Along with direct gradient analysis (Whittaker 1967), various types of clustering are among the methods with most easily interpretable results. Reciprocal averaging or DECORANA (Hill 1979) are the preferred ordinations (e.g. del Moral 1980) which are used to portray the relationship of stands and vegetation types to environmental gradients in the ordination space. Numerous programs specifically designed for analysis of vegetation data are now available (van der Maarel 1979, van der Maarel et al. 1980).

Traditional methods have the advantage of being able to handle large matrices of taxa and samples which is often not possible using numerical methods due to computer hardware and software limitations. Taxa selected to be omitted from the analysis should show little association with others (Goodall 1969). Where the number of taxa and the range of environmental variation covered are large, taxa presence may supply all the information needed for classification; quantitative variables may be needed in subsets (Goodall 1978, Komarkova 1980). Lambert and Dale (1964) found the information content of qualitative data double that of quantitative data.

Moore et al. (1970) determined that the Braun-Blanquet method was the most efficient for general ecological survey; it is a polythetic, subdivisive classification, followed by a linear ordination. Its main advantage is that it displays all floristic information which is lost if only the results of numerical methods such as the ordination diagrams are shown. The same advantage applies to the Daubenmire's method as long as all taxa are included in the association tables.

CLASSIFICATION

The vegetation types resulting from the Daubenmire's approach are very similar to the types resulting from other floristic-based systems which use stand taxa composition as the basis for analysis. Groups of taxa, analogous to the characteristic taxa combination (Westhoff and van der Maarel 1978) of the Braun-Blanquet system, indicate also the Daubenmire's vegetation types.

The diagnostic value of taxa is limited geographically because many of them show different ecological amplitudes in different parts of their distribution area; the diagnostic value of a taxon for a given vegetation type is restricted to a climatically uniform area (Braun-Blanquet 1964, Westhoff and van der Maarel 1978). If no diagnostic or indicator taxa are present, particularly in taxa poor vegetations such as in the Arctic, dominance of taxa may define the vegetation units at the lowest level of the classification hierarchy. Different vegetation strata may be classified individually; the Braun-Blanquet approach classified each stand as a whole because of the close interrelation of layers and their

common substrate (Westhoff and van der Maarel 1978).

The samples which belong to the same vegetation type should vary little in the number of taxa. The uniformity of the units can be also checked with the help of the ratios of taxa in different presence degree or constancy classes. Homotoneity of vegetation types is a synthetic concept parallel to the homogeneity of stands. Homotoneity is determined by comparing similar plots from different stands of the same community type (Westhoff and van der Maarel 1978). An essential step, which is often omitted, is field checking of the newly defined vegetation units.

The names of the habitat types and of Daubenmire's associations are easily correlated with the International Code of the Phytosociological Nomenclature (Barkman et al. 1976) because two names of the dominant and other important taxa are usually included in the names of units under both systems. A uniform system of standard names derived in a standard way is necessary for ordering information and communication (Westhoff and van der Maarel 1978).

The habitat type approach does not provide for objective derivation of higher units of the vegetation type hierarchy based on floristics. Series, the level which groups habitat types, is artificial. For example, Pfister et al. (1977) and Layser and Schubert (1979) defined series as encompassing all habitat types having the same dominant taxon at climax. Layser and Schubert (1979) and others used physiognomic higher units such as formation and subformation to group series.

Both the habitat types and the higher units that group them should be derived using the same criteria and by the same methods. The floristic and physiognomic systems of vegetation classification should be kept separate and parallel because they are based on different classification criteria. Plant series relies on the criterion of dominance of the same taxon which should be used only in the absence of floristic diagnostic taxa groups. The series should be redefined; as defined today, it should not be part of the habitat type classification system, but it could be used for special purposes. The higher-level units in the Braun-Blanquet system often have stronger groups of diagnostic taxa than the lower-level units such as associations. Higher taxa may be used to define higher-level vegetation units in the classification systems based on floristics.

SUMMARY

In general, there is little difference between most methods and results of the habitat-type approach and of other vegetation classification systems based on floristic composition of vegetation such as the Braun-Blanquet approach. All these methods recognize the heterogeneity of taxa distribution but emphasize the interactions between plants in the community. Communities have a certain individuality because of relative discontinuities in the field; ecosystem patterns may be considered a complex mixture of continuity and discontinuity (Whittaker 1956, Westhoff and van der Maarel 1978).

The costs of collecting a certain type of data and the benefits which result from that data should be weighed carefully when resources are limited. Most of the cost of a method in time, funds and other resources are determined by the number of plots, and the amount of and the type of data to be sampled in each plot. An increase in both of these increases time and effort in the field and during data reduction and entry and reporting. Possible errors include selection of inappropriate type, number, or size of plots, repetitive sampling without a substantial increase in quality of the results, collection of unnecessary data, and inadequate coverage of the field reality.

The most important criteria for evaluation of various classification methods are the appropriateness of the method for reaching the objectives of the classification, its efficiency in producing the results, and the closeness of the results to the reality in the field. Subjective plot selection and estimation of data values are the most efficient methods of sampling in large-scale vegetation surveys. Eight to ten plots a day may be sampled using the subjective plot selection, plots with varying size and boundaries which are not predetermined and not marked in the field, and estimating the cover of all taxa and the values of a number of environmental variables.

Sampling should be prioritized in decreasing order of the amount of information in the data, as follows:

1. sampling for diversity of vegetation types and taxa in a given area; this facilitates determination of ecological ranges and optima of taxa within a region, the determination of vegetation types and diagnostic taxa groups, and comparisons between whole regions;
2. sampling for presence degree or constancy of taxa within individual vegetation types; this facilitates the determination of diagnostic taxa, describes the type variability and the distribution of each taxon within each type, and contributes to the knowledge of vegetation types important for the management of the area.

Considerably more information is contained in

less quantitative data covering the entire vegetation universe than in highly quantitative data covering only a small part of it.

The chosen methods should be thoroughly tested and preliminary classifications firmed up or modified by field testing and supplemental sampling. Any new methods should be compatible with the old methods to make the results from different regions comparable. Raw, complete stand data should always be published.

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Quantifying Variables for Classifying Desert Riparian Vegetation [1]

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Abstract.--We classified the vegetation of the lower 160 km of the Colorado River north of Mexico. Wildlife use data were collected for each of the recognized vegetation types. Six vegetation types were recognized on the basis of species of dominant vegetation present. Independent of this we recognized six structural categories on the basis of proportion of the total foliage density occurring in each of three vertical layers. Each of the 23 recognized vegetation types differed from all of the others in dominant plant species present and/or by vertical distribution of the foliage. Principal components analysis was applied to 16 vegetation variables in order to understand major trends in these variables across the 23 vegetation types. The resulting principal components were subsequently used as variables for analyzing the distribution of the vegetation with respect to various environmental features with a view to explaining wildlife use of the vegetation.

INTRODUCTION

Any classification of vegetation is largely arbitrary; therefore it is of utmost importance to clearly state the purpose of the classification (Kuchler 1967). In 1973 we began studying the riparian vegetation of the lower Colorado River, extending from Davis Dam, California-Nevada-Arizona boundary, to the Mexican border. Our major objective was to divide the vegetation into broad categories or types, characterized according to their general floristic and physiognomic characteristics. Our next objective was to determine the densities and diversities of wildlife associated with each vegetation habitat or type.

The classification was to be simple enough that engineers, hydrologists, biologists, etc. could quickly learn and use the classification system and quickly identify habitats in the field by taking only a few, if any, vegetation measurements. They could then quickly and accurately assess a stand of vegetation in terms of habitat classification and wildlife use. In addition to being relatively simple, the classification had to emphasize similarities rather than differences between stands. Although not without merit, emphasizing differences would have been undesirable for our purpose as it would have yielded a classification system defining a large number (hundreds or thousands would be possible) of habitat types. We wanted enough generality for each vegetation type to be represented by a large enough area that wildlife use could be accurately quantified in it at all seasons.

Aerial reconnaissance revealed that the riparian vegetation consisted of intermeshed stands of vegetation often encompassing ten to hundreds of ha. Ground reconnaissance revealed that these stands differed from each other primarily in dominant vegetation and vertical configuration. We then quantified differences and similarities among the various stands. This report emphasizes methods employed in quantifying vegetation data used for classifying vegetation.

DATA COLLECTION

We established 121 km of transects in riparian vegetation in the lower Colordo River valley. Lines or transects were established by cutting swaths 1 m wide through the middle of stands encompassing at least 10 ha, measuring at least 750 m long by 50 m wide. Small patches (<1 ha) of vegetation differing in species composition or structure from the basic type in the stand were bisected by the transect at right angles whenever possible. In no case was a transect situated so that vegetation differing from the stand as a whole, due to a

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local edaphic feature, paralleled the transect at a distance closer than 15 m. Each transect was semipermanently marked at the beginning and end of the transect. A stake with distance from beginning of the transect inscribed on it was driven into the ground every 150 m. A transect 750 m long had five subplots, each 150 m long on each side, for a total of 10 subplots. Longer transects, of course, had more subplots. Vegetation data were collected for each subplot. Each transect was numbered; transect number and directional orientation were recorded on a map.

VEGETATION MEASUREMENTS

In each subplot vegetation measurements consisted of tree density and foliage density as follows:

Tree counts were conducted only once on each transect unless the area was later affected by some major disturbance. Counting was unaffected by amount of foliage present and could be done at any time of year.

Individuals of each species of tree or shrub within 15 m of the transect were counted in each 150-m subplot. Each individual tree was categorized by height (> or <3 m), by presence or absence of mistletoe (Phoradendron californicum), and by its condition (alive or dead).

Sometimes shrubs or trees grew in densities so great that it was not possible to count individuals. Often densely packed individuals provided no more ground cover than trees in less dense areas. Thus 20 trees in one area could equate in terms of ground cover to 200 trees in another area. To solve this problem we measured the height and north-south crown diameter of hundreds of individuals of each tree species growing at various heights in uncrowded conditions. From these data we developed regression equations for determining the ground cover by an individual tree (shrub) of a given height. Thus when we encountered a dense patch of trees or shrubs, we measured the area of the patch and obtained the average height of the trees in it. We then merely divided the area of the patch by the area occupied by the average single tree growing in uncrowded conditions to get the equivalent number of trees or shrubs growing under noncrowded conditions. This method may be applied to all trees and shrubs to obtain a rough estimate of ground cover for a given plant species in an area.

Foliage density estimates were made in all stands annually between May and July; stands undergoing succession (burned and regenerated areas) were measured again in September or October. Relative foliage density estimates were made using the board technique (MacArthur and MacArthur 1961). Sampling was done at three points (50 m, 75 m, and 100 m) on each subplot. Thus on a 750-m long transect, there were 15 points per side for a total of 30 points.

At each sample point the observer paces one step perpendicular to the transect. A second person holds a board (approximately 20 X 40 cm) at a given height behind the nearest green leafy vegetation. The observer stops the second person when green foliage covers one-half of the board. Distance from observer to board was measured with a tape measure or rangefinder. Measurements were recorded in feet because of the scaling of equipment used; also all vegetational calculations were based upon the English system of measures. All measurements were rounded to the nearest 1 ft (0.3 m) except in the first 1 ft, where a distance of 2 in (5 cm) represents very dense vegetation, but 0 means that foliage is absent. Thus any distance >0 but <1 ft was called 1 ft. Often it was difficult to obtain agreement between two observers for distances <1 ft, yet the difference in, for example, the density estimate between 1 in (2.5 cm) and 2 in is large. Rounding to 1 ft resulted in a conservative estimate of foliage density in very dense places, but yielded results reproducible by other observers. Foliage density determinations were made vertically at 0.015 m, 0.6 m, 1.5 m, 3.0 m, 4.5 m, 6.0 m, 7.5 m, 9.0 m, and every 3 m thereafter until no vegetation was present. Theoretically one should use a ladder to make measurements at higher levels. This was impractical. We used a rangefinder to locate a point, for example, at 8 m, then estimated as carefully as possible the distance to a second point where leaves would cover half of the board. Plant species contributing to foliage densities at each point were recorded.

Distances were measured to the nearest 1 ft within the first 10 ft (3 m), because the foliage density index is more sensitive to vegetation located nearby. Measurements beyond this were estimated with the aid of a rangefinder. In sparse areas the distance to trees and shrubs with foliage was measured from only one sample point, the point to which they were closest. Data were recorded as in Vegetation Management Final Report (Chapter 2; Anderson and Ohmart in prep.).

Each plant distance measurement was converted to surface area per cubic unit of space according to the formula:

$$K = \frac{\log_e 2}{D} = \frac{0.693}{D}$$

where K is the foliage density and D is the measured distance. Foliage density per subplot is the sum of the average of the three measurements taken at each vertical plane. For example, foliage density at 1.5 m in one subplot for which the distances were 9, 15, and 2 ft would be calculated as follows:

$$\left(\frac{0.693}{9} + \frac{0.693}{15} + \frac{0.693}{2}\right) \text{divided by } 3 = 0.1556$$

Foliage density at 3 m for distances of 1, 2, and 3 ft would be:

$$\left(\frac{0.693}{1} + \frac{0.693}{2} + \frac{0.693}{3}\right) \text{divided by } 3 = 0.4217$$

The density for the two vertical planes is 0.1556 + 0.4217 = 0.5773. If no green foliage occurred at a particular point, a zero was used in the calculations. A sample set of foliage density calculations is shown in table 1.

Table 1.--Sample foliage density estimates used for calculating patchiness and foliage height diversity.

	Foliage density (ft^2/ft^3)				
Plot	0.15 m	0.6 m	1.5 m	3.0 m	4.6 m
1	0.16	0.20	0.29	0.10	0.01
2	0.12	0.15	0.23	0.06	--
3	0.08	0.09	0.27	0.09	0.01
4	0.28	0.15	0.09	0.01	0.00
5	0.19	0.22	0.09	0.02	0.00
6	0.18	0.34	0.29	0.10	0.02
7	0.07	0.31	0.31	0.03	0.01
8	0.08	0.18	0.31	0.02	--
9	0.15	0.16	0.32	0.03	--
10	0.23	0.15	0.13	0.01	--

	Patchiness index				
	0.15-0.6 m	1.5-3.0 m	4.6-6.0 m	≥7.5 m	Total
Mean total density	0.35	0.28	0.00	--	
PI(s^2)	0.01	0.01	0.00	--	0.02

	Calculation of foliage height diversity				
	0.15-0.6 m	1.5-3.0 m	4.6-6.0 m	≥7.5 m	Total
Mean total density	0.35	0.28	0.00	0	0.63
Proportion (p_i)	0.55	0.44	0.01	0	
$\log_{10} p_i$	-0.26	-0.36	-2.20	0	
$p_i \log_{10} p_i$	-0.14	-0.16	-0.01	0	FHD = 0.31

TREATMENT OF DATA

Vertical Diversity

Vertical or foliage height diversity (FHD) for each transect was calculated according to information theory (Shannon and Weaver 1949):

$$H = -\sum_{i}^{n} p_i \log_n p_i$$

where H equals FHD and p_i is the proportion of total foliage density contributed by the density at height level i (Sample calculations are shown in table 1).

Horizontal Diversity

Horizontal diversity (or patchiness) is a structural feature of a habitat describing the regularity of vegetation distributed in the horizontal plane. A citrus orchard with roughly equal-sized and evenly spaced trees has little horizontal diversity. Patchiness or diversity is greater in a honey mesquite (*Prosopis glandulosa*)-quail bush (*Atriplex lentiformis*) habitat with irregularly spaced trees and shrubs of different heights. Diversity in the horizontal plane can be calculated for any vertical level from which foliage density estimates are made.

Many stands of Colorado River riparian vegetation include a shrubby layer up to about 1 m. We chose foliage density estimates from 0.15 m and 0.6 m to represent this vertical layer. Foliage density in this layer was the sum of the density at 0.15 m and 0.6 m. A majority of stands had another layer extending from about 0.6-4.5 m. We chose foliage density estimates at 1.5 m and 3.0 m to represent this layer. Many stands have a third layer, usually poorly developed, extending above the second layer for an additional 2 or 3 m. We chose foliage density estimates at 4.5 m and 6 m to represent this layer. More than 95% of lower Colorado River riparian vegetation had virtually no vegetation above 7.5 m. Exceptions included occasional stands of athel tamarisk (*Tamarix aphylla*), cottonwood (*Populus fremontii*), or willows (*Salix gooddingii*), with individual trees reaching 30 m. We therefore recognized a fourth layer with foliage ≥7.5 m.

Horizontal diversity was the variance associated with the mean total foliage density for each vertical plane across all subplots. For example, summed foliage densities for 0.15 m and 0.6 m in each plot (table 1) were averaged to obtain mean foliage density for the layer 0.0-0.6 m, in this case 0.348. Horizontal diversity is the variance or standard deviation squared = 0.010 associated with mean total foliage density. This procedure was repeated for each vertical layer. Total horizontal diversity is the sum of the variances for all layers.

Note that in calculating horizontal diversity we are assessing the variance between subplots. Therefore, if horizontal diversity is thought of as patchiness, we are defining a patch as a unit 150 m long and as wide as the distance from the transect to the edge of the stand under study. Choice of this patch size was based on evidence that many common birds in the area use patches of about this size (Anderson and Ohmart 1981, Conine 1982, Anderson, Romano, and Ohmart unpubl. ms). Thus it is possible that an area rated very patchy on a smaller scale could be rated homogeneous on our scale.

Since 0.00 and 0.69 represent minimum and maximum foliage density values, respectively, maximum horizontal diversity or patchiness for a given layer is 0.238. Since there are four layers, maximum horizontal plane diversity is 4(0.238) or 0.9522. Since this is very nearly 1.0, the sum of the diversity for the four layers closely represents the percent of maximum diversity possible for an area.

CLASSIFYING THE VEGETATION

Dominant Vegetation

Tree and shrub counts along transects revealed that salt cedar (*Tamarix chinensis*) was virtually the only tree species present in many stands encompassing 10 ha or more. There were also such stands of honey mesquite and arrowweed (*Tessaria sericea*). Thus these three species were easily recognized as dominant for three vegetation types. Other major vegetation types were more difficult to identify. All other stands included salt cedar in high numbers. In some of these stands the numerical dominance of salt cedar was shared (constituted at least 5% of total trees present) by other species. Given that cottonwood and willow were considered as ecological equivalents, numerical dominance was never split among more than two species. Based on dominant tree or shrub species present, we recognized six vegetation types: (1) honey mesquite; (2) salt cedar; (3) salt cedar mixed with screwbean mesquite (*Prosopis pubescens*); (4) salt cedar mixed with honey mesquite; (5) salt cedar mixed with cottonwood and/or willow; and (6) arrowweed (table 2).

Vertical Configuration

In order to quantify the extent of similarity in vertical configuration among transects, we calculated overlap between compared stands in proportional distribution of foliage among three layers: 0.0-0.6 m, 0.61-4.49 m, and $\geq$4.5 m. It was not necessary to consider four layers (as in calculations discussed above) because the few areas with very tall vegetation (>6 m) could be easily separated from stands with only three layers of vegetation by considering overlap in three vertical bands. Overlaps were calculated using (Horn 1966):

$$R_o = \frac{\Sigma (x_i + y_i) \log(x_i + y_i) - \Sigma x_i \log x_i - \Sigma y_i \log y_i}{(X + Y) \log(X + Y) - X \log X - Y \log Y}$$

For the compared stands, x_i and y_i represent the proportion of total foliage density occurring at vertical band i. X and Y represent total foliage density. From a matrix of these overlap values,

Table 2.--Mean percent of trees of various species per 150-X-15-m subplot in riparian vegetation along the lower Colorado River. Dominant vegetation is underlined. Arrowweed, the sixth vegetation type, is not included in this table because trees were not present in this vegetation type.

Numerically dominant tree species	Number of subplots	Mean percent of total trees: Salt cedar	Honey mesquite	Screwbean mesquite	Cottonwood and/or willow
Honey mesquite	254	0	99	1	0
Salt cedar	216	99	0	1	0
Salt cedar-honey mesquite	38	54	46	0	0
Screwbean mesquite-salt cedar	230	59	2	38	1
Cottonwood and/or willow-salt cedar	194	60	1	4	35
Total/mean	932	51	29	11	9

including all possible two-way comparisons between stands, a dendrogram (fig. 1) was constructed from:

$$\alpha C,AB = \frac{\alpha C\,A + \alpha CB}{2}$$

which simply states that overlap in the vertical distribution of foliage of stand C with stands A and B is equal to average overlap of C with A and C with B (Cody 1974). The dendrogram was interpreted as revealing existence of six categories based on vertical configuration. Each stand within a category (designated I-VI) had a more similar vertical configuration to other stands included in that configuration than to any stand within any other category. Observe that this determination was based on proportional vertical foliage distribution; absolute foliage density had nothing to do with it. That is, the vegetation within any category (or structural type) could theoretically include dense as well as sparse stands.

Profiles

Profiles of the six recognized vertical distributions (fig. 2A) indicate that there was a continuum extending from stands with a majority of foliage in the upper bands (Types I and II) to those with a majority of foliage in the middle band (Types III and IV) to those with a majority of foliage in the lower band (Types V and VI). Note that this indicates foliage distribution, not foliage density, in the vertical dimension.

ANALYSIS OF HETEROGENEITY

Because our stands were large (at least 10 ha), heterogeneity was inevitably present as a result of several factors. Local edaphic features were a frequent source of heterogeneity. For example, in one large stand of honey mesquite there was a narrow finger (20-30 m wide), representing an old silted-in oxbow moister than the surrounding area. For this reason salt cedar, seep willow (Baccharis salicifolia), and Goodding willow occurred there. Local heterogeneity in soil layering and structure also introduced heterogeneity. For example, a dense clay soil type could cause a very local concentration of soil electrolytes. Vegetation growing in such soil often attains less stature and biomass (Anderson and Ohmart 1982, Anderson, Ohmart, and Disano unpubl. ms), and therefore vertical differentiation is simpler than that of adjacent vegetation. Such variation was so frequent that it was not feasible or desirable to delineate it within an otherwise homogeneous stand. Although such delineation may be important, it was beyond the scope of our study to do so. Such delineation would have required more time and money than was available to map the vegetation and acquire meaningful wildlife use data. These small parcels typically ranged in size from <1 ha to about 5 ha. Areas smaller than about 10 ha could not be accurately plotted on maps of the scale (1:9449 cm) we were preparing.

Another source of variation included widely distributed individual trees of formerly more widely distributed species. For example, cottonwood

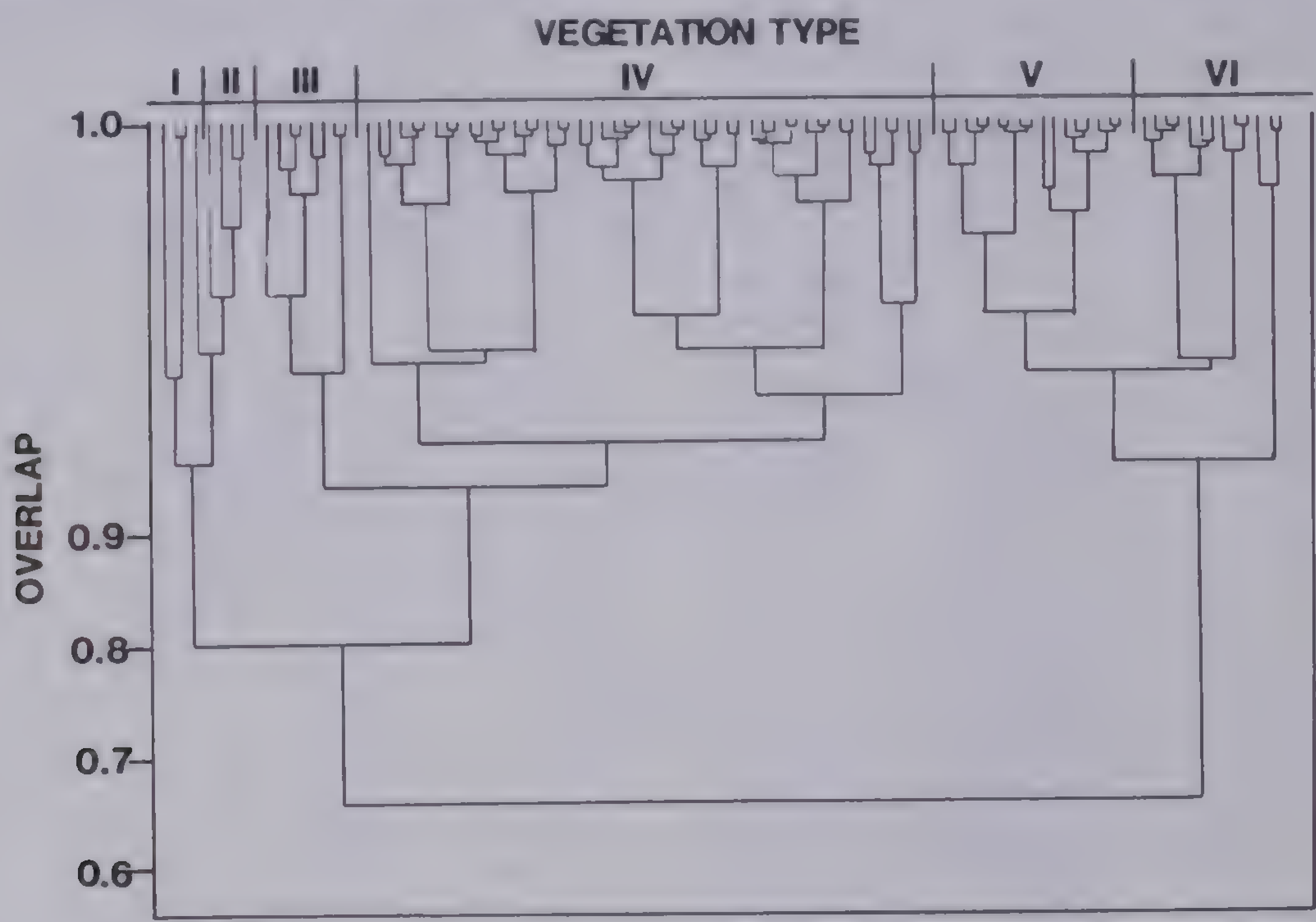
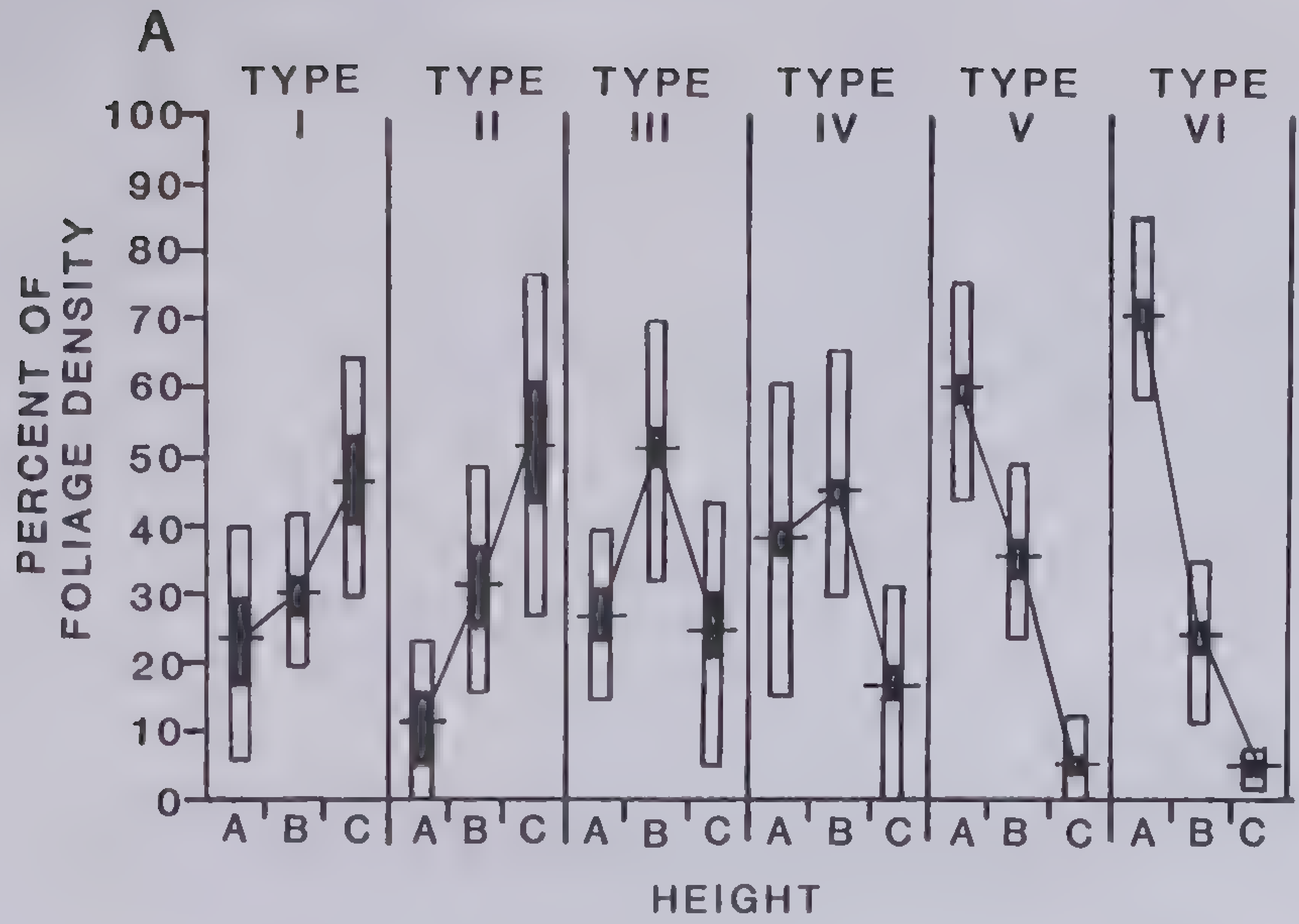


Figure 1.--Dendrogram showing relationships based on overlap in foliage distribution.



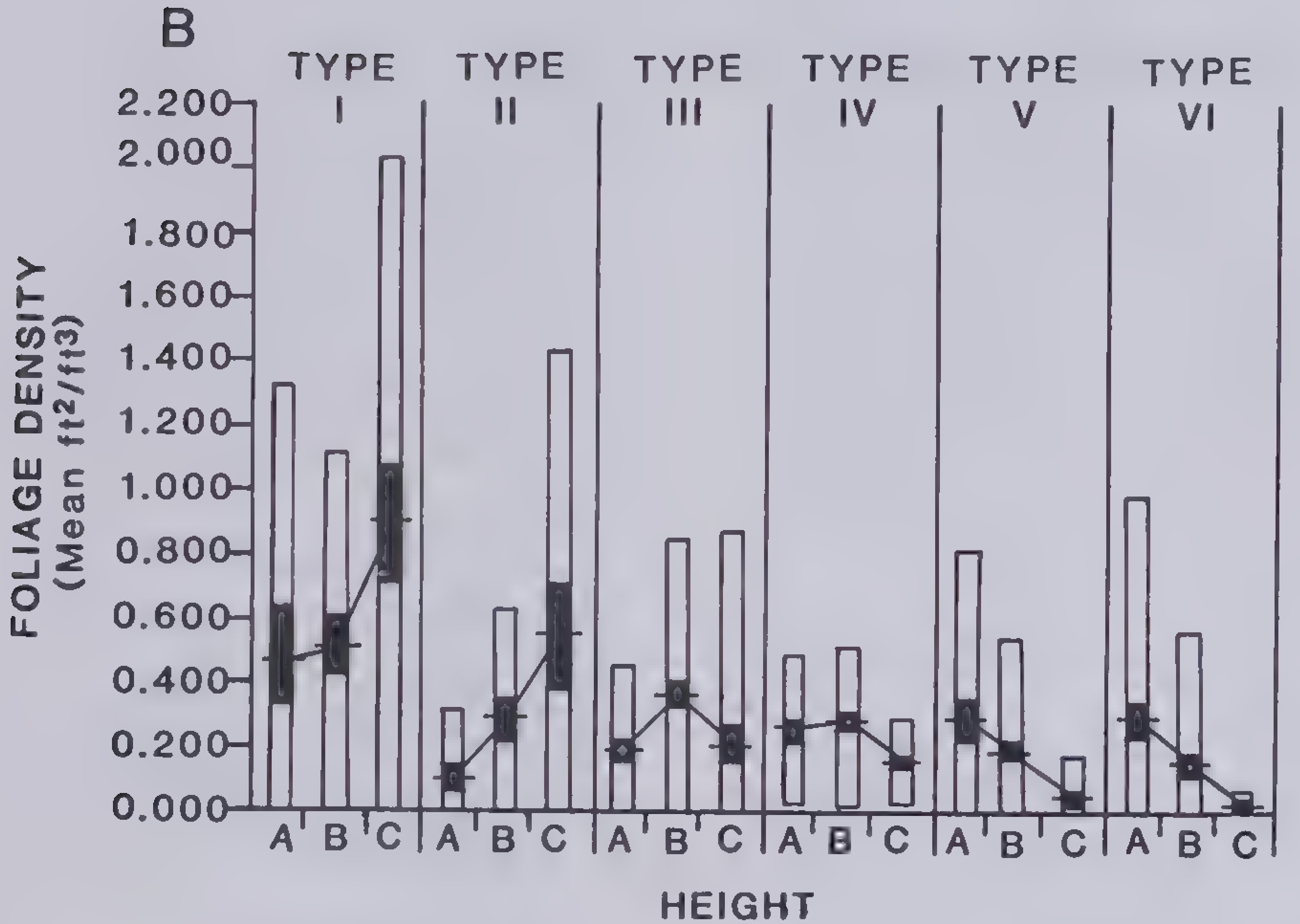


Figure 2.--(A) Proportional distribution of the vegetation in three vertical layers. (B) Variation in foliage density between subplots within all structural types at each of three vertical levels. Note that the proportional distribution leads to clear differentiation of the vegetation types, but that foliage density does not. Horizontal lines represent mean values; large rectangles represent ± 1 standard deviation; small rectangles represent ± 2 standard errors. A = 0.0-0.6 m; B = 0.61-4.49 m; C = $\geq$4.5 m.

and willow trees, often found as widely scattered individuals or as small clumps (20 X 20 m) of trees, are relicts of a gradually disappearing habitat (Ohmart et al. 1977).

Fire, another source of within-stand heterogeneity, in varying degrees and at various times, has affected nearly every stand of vegetation along the lower Colorado River. When a stand is burned, not all parts of it burn with equal intensity; some corners or clumps remain intact. Parts of a stand may have been burned more than once, so at any given time not all parts of a stand are at precisely the same stage of post-fire recovery. Even when burned evenly, not all parts of a stand recover at precisely the same rate. Thus at some level of analysis, considerable heterogeneity could be found within any fundamentally homogeneous stand.

Heterogeneity Between Subplots

The 150-m subplots along transects traversing stands of a given structural type revealed much of the heterogeneity within a habitat. This heterogeneity can reflect differences between subplots in vertical foliage distribution (fig. 2A), in foliage density (fig. 2B), or in both of these. A subplot encompassed between 0.2 and 1.9 ha, depending on the width of the stand; most subplots were nearer the maximum figure. This is a fact rendering our system of classification entirely unsuitable for stands less than about 2 ha; the system becomes more suitable as plot size approaches 10 ha. For example, within vegetation classified as structural Type IV, vertical configuration in the various subplots more frequently resembled Type IV (table 3) than any other structural type. However, in the strictest sense it is not appropriate to give structural type designations to subplots constituting a certain structural type. Structural types were defined on the basis of transects with similar average vertical foliage distributions. The foliage distributions were determined on the basis of measurements taken in subplots. That it is wrong to classify subplots (or any area <10 ha) can be seen from the following analogy.

Suppose that all books in six private libraries were measured and mean heights were found to be 220, 230, 240, 250, 260, and 270 cm for collections I-VI. It would be improper to examine books in collection IV and to conclude that those $\leq$240 cm in height came from collections I, II, or III and that all books $\geq$260 cm in height came from collections V and VI. Desirable as it might be to know the origin of the books in collection IV, such a determination simply cannot be made from the evidence presented.

We present the data in table 3 merely to emphasize (1) that there was heterogeneity between subplots and (2) that it is not valid to obtain foliage measurements for a 5-ha plot and then to determine its vegetation type. This would be analogous to having a book 262 cm and concluding that it came from collection V. It really could have come from any of the collections. Desirable as it may be to be able to classify a 5-ha stand and to assess the wildlife use associated with it, such a determination is not possible with our data. We reiterate that this is compatible with the objectives of this study. A classification at a smaller scale would have led inexorably to a proliferation of vegetation types recognized. This would have been incompatible with the objective of emphasizing elements of similarity between stands rather than differences. More important, we have learned that classification at a smaller scale would have led to a cloudy or erroneous picture of how wildlife used riparian vegetation. Cloudiness begins to appear at a scale of about 20 ha (Anderson et al. in press), and an opaqueness emerges from analyses at a scale of about 2 ha (Rosenberg 1980, Engel-Wilson 1982, Anderson and Ohmart unpubl. ms); i.e., only weak wildlife use patterns are discernible at a scale of $\leq$20 ha, and wrong or no impressions emerge at a scale of $\leq$2 ha. Investigators working in other habitats have reported similar findings (Wiens 1981, Wiens and Rotenberry 1981a, 1981b).

Table 3.--Each of six recognized structural types (see text) was composed of subplots. Variation in vertical configuration among subplots within each structural type is indicated by the data below. See text for discussion of tautology in this type of analysis.

Structural type	Subplots No.	Percent of subplots of structural type I	II	III	IV	V	VI
I	36	38	31	9	9	13	0
II	30	0	63	20	17	0	0
III	154	6	9	66	11	9	0
IV	366	1	4	23	38	19	15
V	291	0	0	8	4	59	30
VI	279	0	0	0	8	18	75

Some of our conclusions about wildlife use of riparian vegetation along the lower Colorado River at the vegetation (habitat) type scale have been experimentally tested and confirmed (Meents et al. 1982, Anderson and Ohmart unpubl. ms). Other tests are in progress. It is inevitable that a classification made for our purpose will often fail when used for other than the intended purposes.

Heterogeneity in Number and Species of Trees

The intra-stand variation in number and species of trees as revealed by subplot analysis was also extensive (table 4). We showed above how we arrived at a classification based on species or combinations of numerically dominant species which led to the recognition of six vegetation types with as many as six vertical configurations. Of a theoretical total of 36 vegetation (habitat) types, 23 were actually present.

Intra-habitat variation in number of trees per subplot, in general, fits a normal distribution. Vegetation types (habitats) with Type I or II vertical configurations tended to have more trees other than salt cedar per subplot than Type V or VI

Table 4.--Average number of trees (±1SD) per subplot in each of 23 recognized riparian habitat types along the lower Colorado River.

Vegetation type and number of subplots		Number of trees per 150-X-50-m subplot: Salt cedar $\bar{x}$	Salt cedar SD	Cottonwood $\bar{x}$	Cottonwood SD	Willow $\bar{x}$	Willow SD	Screwbean mesquite $\bar{x}$	Screwbean mesquite SD	Honey mesquite $\bar{x}$	Honey mesquite SD	Percent of subplots with no trees of dominant species
Salt cedar												
I	18	95	20	0	0	0	0	0	0	2	20	0
II	8	47	19	0	0	0	0	0	0	0	0	0
III	28	74	25	0	0	0	0	7	13	0	0	0
IV	32	163	105	0	0	0	0	0	0	0	0	0
V	109	133	146	0	0	0	0	1	3	0	0	1
VI	20	31	50	0	0	0	0	0	0	0	0	0
Salt cedar-cottonwood/willow												
I	18	52	13	59	27	87	23	0	0	0	0	0-0
II	10	129	46	38	22	49	34	0	0	0	0	0-0
III	62	130	147	19	44	54	66	13	23	6	7	0-6
IV	52	38	53	0	0	29	17	7	15	0	0	3-8
V	30	44	49	0	0	17	21	0	0	0	0	0-0
VI	22	19	32	1	1	1	26	0	0	0	0	0-50
Salt cedar-screwbean mesquite												
II	10	63	24	2	4	1	1	96	17	0	0	0-0
III	40	49	43	0	0	0	0	18	15	0	0	0-8
IV	78	60	58	0	0	4	25	39	31	0	0	1-6
V	84	45	39	0	0	0	0	44	62	0	0	0-8
VI	18	45	55	0	0	0	0	6	6	0	0	0-22
Salt cedar-honey mesquite												
IV	38	41	53	0	0	0	0	0	0	35	68	2-6
Honey mesquite												
III	24	0	0	0	0	0	0	<1*		93	50	0
IV	122	0	0	0	0	0	0	0	0	31	42	1
V	56	0	0	0	0	0	0	0	0	12	7	2
VI	52	0	0	0	0	0	0	<1*		9	7	2

*Standard deviation not calculated where $\bar{x}$ <1.

configurations (table 4). Coefficients of variation tended to increase inversely with the mean number of trees. This suggests a decrease in foliage density from Type I through Type VI. This is investigated in the next section.

Intra- and Inter-habitat Variation in Foliage Density

Variation in foliage density between subplots within all structural types is considerable at all vertical levels (fig. 2B). It is important to note that by simply measuring the foliage density at a particular level in a small part (about 2 ha) of a stand one cannot, with any certainty, classify the stand as we have defined it. Type I habitats had more foliage at all levels than other structural types. Type II habitats tended to be denser in the upper layer and sparser at the lowest level than all other structural types. Differences among the other structural types in total foliage density were slight and imperceptible in the field.

Inter-habitat Variation in Horizontal Diversity

Horizontal diversity or patchiness at the layer 0.0-0.6 m tended to be greatest in habitats of structural Types I, V, and VI (table 5). It is reasonable that Type I would be patchy in this layer because it had a relatively even distribution of foliage among layers (fig. 2A). Since low-level vegetation usually does not grow densely in heavily shaded areas, this means there must have been patches of tall vegetation with little understory alternating with patches of short, dense vegetation. This would lead to patchiness in the upper as well as in the lower level. Thus Type I vegetation also had large overall patchiness index values. Types V and VI had high patchiness values when dense patches alternated with nearly bare areas. Low patchiness

Table 5.--Index to relative foliage diversity in the horizontal plane in 23 riparian habitat types found along the lower Colorado River. For each vertical layer horizontal diversity or patchiness is the variance of foliage density at that layer. Total horizontal diversity is the sum of diversity at the vertical layers.

Vegetation type	Number of subplots	Vertical foliage layer 0.0-0.6 m	0.6-3.0 m	≥4.5 m	Total
Salt cedar					
I	18	0.12	0.06	0.13	0.31
II	8	0.02	0.01	0.05	0.08
III	28	0.01	0.06	0.03	0.09
IV	32	0.04	0.06	0.02	0.12
V	110	0.03	0.02	0.00	0.05
VI	20	0.37	0.13	0.00	0.50
Cottonwood-willow					
I	18	0.12	0.09	0.26	0.47
II	10	0.00	0.01	0.09	0.09
III	62	0.03	0.05	0.17	0.25
IV	52	0.06	0.08	0.05	0.19
V	30	0.06	0.05	0.02	0.13
VI	22	0.11	0.01	0.00	0.12
Screwbean mesquite					
II	10	0.01	0.05	0.38	0.44
III	40	0.01	0.02	0.05	0.07
IV	78	0.04	0.03	0.04	0.11
V	84	0.14	0.04	0.00	0.18
VI	18	0.03	0.00	0.00	0.04
Salt cedar-honey mesquite					
IV	38	0.04	0.04	0.00	0.08
Arrowweed					
VI	30	0.07	0.02	0.00	0.09
Honey mesquite					
III	24	0.01	0.12	0.04	0.17
IV	122	0.04	0.05	0.12	0.20
V	56	0.03	0.02	0.00	0.05
VI	52	0.01	0.00	0.00	0.11
Mean		0.06	0.04	0.06	
Standard deviation		0.08	0.04	0.10	

values at 0.0-0.6 m could mean that the area was very sparse overall or that dense vegetation was present and evenly distributed throughout the stand. Mean patchiness was about the same in the various vertical layers, although variation was greater in lower and upper layers (table 5).

It is difficult to describe trends in the patchiness data. The difficulty is compounded if we try to visualize trends in the vegetation across all variables (tree counts, variations in vertical configuration, foliage densities and patchiness) simultaneously. We therefore applied principal components analysis as an aid in recognizing general patterns in this complex vegetational data set.

PRINCIPAL COMPONENTS ANALYSIS OF THE VARIATION AMONG HABITATS

We used principal components analysis (PCA) to help describe the main differences among the 23 habitat types. For this analysis we used 16 variables (table 6) obtained from 1975-1979. All data were transformed ($\log_{10}$ of N + 1 for counts and square root for proportions and diversities) in order to meet assumptions about normality. Transformed data were standardized so that the mean of the entire matrix did not deviate significantly from zero and the standard deviation was approximately 1; thus all variables contributed equally to the analysis.

In order to be certain that derived PC's were not statistical artifacts, we performed a PCA on data for each year separately (Karr and Martin 1981), with each of four years constituting a separate data set. These separate analyses yielded similar results (Meents et al. 1981).

In view of the similarities between years, we performed a PCA on the four-year combined data set. This yielded four PC's (table 6), which accounted for 76% of the variance in the total data set.

Table 6.--Loadings of 16 vegetation variables on the VARIMAX rotated axes for each of four principal components. Data are from 23 riparian habitats occurring along the lower Colorado River. The explained variance for each variable is at the right and the percent of the total variance for all variables explained by each principal component is given at the bottom. Variables contributing $\geq$0.5 to a PC are underlined.

Variables[a]	Principal component I	II	III	IV	Percent variance explained
PI 0.0-0.6 m	0.15	-0.05	0.85	0.03	74.8
PI 0.6-4.5 m	0.70	0.09	0.34	0.27	68.7
PI $\geq$4.5 m	0.92	-0.12	-0.13	-0.12	89.2
PI sum	0.89	0.07	0.22	-0.09	85.4
FD 0.0-0.6 m	0.03	0.08	0.90	-0.13	83.4
FD 0.6-4.5 m	0.89	-0.08	0.16	0.03	82.5
FD $\geq$4.5 m	0.84	-0.22	-0.20	-0.16	82.0
FD sum	0.88	-0.09	0.06	-0.25	84.9
FHD	0.71	-0.25	-0.51	0.02	82.7
Shrubs	-0.26	0.67	-0.01	0.19	55.2
Honey mesquite	0.05	0.90	-0.09	-0.04	82.2
Mistletoe	0.23	0.85	0.08	0.12	70.3
Salt cedar	0.16	-0.75	-0.11	0.32	70.3
Screwbean mesquite	0.12	-0.18	-0.38	0.59	53.9
Cottonwood/willow	0.31	-0.06	-0.09	-0.71	61.2
PSC	-0.16	-0.81	-0.11	0.09	70.2
Percent of total variance explained	35.0	20.9	12.8	7.0	75.7

[a] PI = patchiness index
FD = foliage density
FHD = foliage height diversity
PSC = proportion of total trees which are salt cedar

Foliage density and horizontal diversity measures above 0.6 m and overall FHD loaded high ($\geq$0.50) on this axis and described a trend going from high to low foliage density and diversity across habitat types. PC II explained 21% of the variance and described a trend going from areas with many honey mesquite trees with mistletoe and shrubs and few salt cedar to areas with none of the former and many of the latter. PC III described a trend going from areas with much foliage density and horizontal diversity at 0.0-0.6 m to areas with low values for these variables and explained 13% of the variance. Finally, PC IV described a trend going from areas with many screwbean mesquite and salt cedar trees to areas with few individuals of these species and with many cottonwood and willow trees.

We can study factor score values (in factor analysis) to evaluate whether or not PC's are a realistic representation of some observable features of the riparian vegetation. Factor scores range from roughly 3.0 to -3.0. From figure 2B we see that foliage density and vertical diversity were high in Type I vegetation on average and that Types V and VI had low foliage density and vertical diversity. We also know that Type I vegetation had the highest horizontal diversity (table 5). From this we would predict that Type I vegetation would have a high score on PC I and Types V and VI would have low scores (table 7).

On PC II we expect stands of salt cedar to have maximum negative scores and stands of honey mesquite to have maximum positive scores. Again, this was demonstrated in factor analysis.

From the information in figure 2B we would predict that vegetation types with Type I, V, and VI configurations would have high positive scores for PC III (low-level foliage density and diversity), assuming roughly the same horizontal diversity. In fact salt cedar Type VI had a factor score of 3.0, and cottonwood-willow Type I had a score of 2.0. All Type V and VI habitats had above-average (positive) scores except screwbean mesquite Type V and honey mesquite Type VI, both of which were near zero. This suggests that even though a large proportion of their foliage was between ground level and 0.6 m, the distribution in the horizontal axis was fairly even; that is, they had low horizontal diversity at this level and/or density was not great. In fact screwbean mesquite Type V ranked

Table 7.--Factor scores of 23 riparian habitat types on each of four principal components. Mean factor scores for each principal component do not deviate significantly (P>0.1) from a mean of 0.0 and standard deviation of 1.0.

	Principal component			
Vegetation type	I	II	III	IV
Salt cedar				
I	0.29	-1.02	-1.13	-0.91
II	0.27	-0.64	-0.64	-0.51
III	-0.50	-0.46	-0.78	0.34
IV	-0.01	-1.23	0.31	0.63
V	-1.02	-0.80	0.13	0.30
VI	-0.32	-0.96	3.00	-0.21
Cottonwood/willow				
I	3.19	0.15	1.97	-0.43
II	0.32	0.29	-2.16	-1.62
III	1.62	0.05	-0.12	-0.63
IV	0.59	-0.36	0.22	0.78
V	0.06	-0.75	0.46	-0.27
VI	-1.06	-0.71	0.58	-1.09
Screwbean mesquite				
II	0.71	-0.53	-1.41	1.41
III	0.03	-0.25	-1.80	0.75
IV	0.31	0.20	-0.60	1.34
V	-0.56	-0.35	-0.09	0.79
VI	-0.90	-0.80	0.13	0.30
Salt cedar-honey mesquite				
IV	-0.17	0.71	0.03	0.56
Arrowweed				
VI	-0.85	-0.05	0.63	-0.72
Honey mesquite				
III	0.87	2.04	0.13	0.75
IV	-0.14	2.19	0.55	0.49
V	-0.71	1.66	0.41	0.02
VI	-1.23	-0.05	0.63	-0.72
Mean	0.03	-0.08	0.01	0.06
Standard deviation	0.98	0.94	1.11	0.98

17th for foliage density at 0.0-0.6 m and honey mesquite Type VI ranked 18th for horizontal diversity at 0.0-0.6 m (table 6). A low rank and a high rank would tend to cancel each other, resulting in a net score near zero.

PC IV indicated that there were habitats with many screwbean mesquite trees and others with many cottonwood or willow trees. That such areas existed is clear from table 4. We would expect habitats dominated by cottonwood and/or willow trees to have the maximum negative scores and areas dominated by screwbean mesquite to have the maximum positive scores. It will be noted (table 6) that salt cedar loaded 0.32 on this axis, thus salt cedar habitats should also have positive scores. Since all cottonwood-willow habitats included some salt cedar trees, such habitats would not have as high negative scores as they would if salt cedar were absent. Screwbean mesquite habitats had the highest scores on PC IV, and cottonwood-willow habitats, in general, had high negative scores. Cottonwood-willow Type IV had a positive score because screwbean mesquite constituted 9% of the total trees and salt cedar an additional 51% (table 4). Cottonwood and willow trees composed only 39% of the total trees.

In conclusion, PCA summarized a complex data set involving 16 variables and provided a smaller set of principal components which correspond to readily observable features in the field. The analysis revealed that foliage density and diversity measures above 0.0-0.6 m levels (i.e., ≥0.6 m) area highly intercorrelated and that they included vegetation types which are tall, dense, and vertically and horizontally diverse (Type I habitats), but there are those habitats with little foliage density and diversity above the 0.0-0.6 m level (Type VI habitats). The analysis revealed some very obvious features of the vegetation (there were stands where salt cedar was the only tree species present and stands with dense and horizontally diverse vegetation), but it also revealed variation hidden if only the dominant vegetation and vertical configuration are known. The distribution of factor scores for each PC did not deviate significantly from normal. Because the distributions of PC's were normal and because they corresponded to readily apparent physiognomic and floral characteristics in the field, they could be used as variables in parametric data testing, including analysis of variance, simple correlation analysis, and multiple linear regression.

Examples of Analyses Using This Vegetation Classification System

Correlation analysis using PC's as variables can be used to show relationships between the PC's and physical and chemical features of the 23 habitats (Anderson et al. in press, Anderson and Ohmart 1982). We routinely use wildlife density and species richness values typical of the different habitats at various seasons to indicate their value to wildlife and to test ecological theories (Anderson and Ohmart 1979, 1981, 1982, in press, Meents et al. 1981, 1982, in press, Laurenzi et al. 1982). Many of the results in these studies have been confirmed by using other analytical techniques (nonparametric statistics, discriminant functions analysis) at the transect level rather than the habitat level of analysis (Rice et al. 1980, in press a, b) or by experiments involving manipulations of the vegetation (Anderson et al. ms, Meents et al. 1982). A major use of these data has been for designing wildlife enhancement projects (Anderson et al. 1978, Anderson and Ohmart 1978, in press). They can also be used for making habitat assessments in preparing impact statements and assessments (e.g., Benham, Blair, and Affiliates 1981, 1982).

Though we stress the importance of structure to wildlife use, it should be emphasized that tree and shrub species composition are extremely important management considerations for wildlife. If this were not true, then salt cedar Type II would equal the wildlife values of cottonwood-willow habitats of the same structure type, and it does not.

SUMMARY AND CONCLUSIONS

Detailed analysis of the vegetation of an area is necessary before accurate assessment of relationships between vegetation characteristics and abiotic features can be made or before value of the vegetation to wildlife can be accurately determined. It should be remembered that when the vegetation over a large area is classified it will be artificial to some extent because almost all environmental variables change gradually across space, yet boundaries to habitats are usually precisely drawn. Vegetational variation will always be ignored at some level with any system of classification. One must decide on a classification system based on (1) the purpose of the classification, (2) the available time, (3) size of the area, (4) manpower requirements, and (5) availability of funds.

The analytical procedures used to develop our classification system are complex, but use of the system is simple. A potential user, reasonably satisfied with the statistical treatment, can apply the system by determining (1) that the stand being investigated encompasses at least 10 ha, (2) the species composition, and (3) the vertical configuration of the stand. These determinations can be made with maps drawn to scale and by observation from a few vantage points. Visual estimates of vertical foliage distribution and of dominant vegetation can be documented by making a few measurements and counts. With this information the assessor can consult references such as Anderson and Ohmart (1977) to determine mean avian densities (with confidence limits) and relative rodent densities in order to evaluate wildlife use of the area. Theory testing, such as mentioned above, would require a complete set of measurements and counts with which more sophisticated analysis could be conducted.

We developed methods and used methods already available in creating a meaningful vegetation analysis that was successful for our intended purposes. That does not mean our methods are the best or that they will necessarily succeed in other areas, but we hope that by studying the procedures we used, other investigators will be able to save time in developing a system that will work well for them.

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Climax Forest Series of Northern New Mexico and Southern Colorado[1]

Robert L. DeVelice and John A. Ludwig[2]

Abstract.--A habitat type classification was developed for the forests of northern New Mexico and southern Colorado based on 617 sample plots. A total of seven climax series are here defined. Most series encompass considerable habitat type variation. Series and habitat type classifications aid effective forest management by providing a means of land stratification based on biotic potential.

INTRODUCTION

Land areas capable of supporting similar plant associations at climax are classified as the same habitat type (Daubenmire 1968). Since natural vegetation integrates all impinging environmental factors a given habitat type encompasses a relatively narrow range of environmental variation (Daubenmire 1976). Habitat type classifications of forests have proven to be of high utility to land managers (Layser 1974). The main advantage of habitat type classifications is that they provide a permanent and ecologically-based system of land stratification (Pfister et al. 1977).

Forest habitat type classifications have been developed for 30 areas in the western United States (Pfister 1981). Although the coverage of these treatments is large, extensive areas lacking habitat type investigations remain. Previous to this study, little documentation of the forest vegetation of northern New Mexico and southern Colorado had taken place. Moir and Ludwig (1979) described mixed conifer and spruce-fir forests in northern New Mexico but did not sample the extensive ponderosa pine forests. Vegetation studies are generally lacking for the forests of southern Colorado. Those that have been performed involved limited sampling areas, e.g., Peet (1981) sampled the Spanish Peaks, Dix and Richards (1976) sampled primarily on Missionary Ridge in the San Juan Mountains, Langenheim (1949) sampled in the vicinity of Crested Butte, Colorado (slightly north of the study area)).

The objective of this study was the identification and description of forest habitat types in the mountains of northern New Mexico and southern Colorado. Reported here are descriptions of the climax series and general relationships of major habitat types. Complete habitat type descriptions will appear in a upcoming Forest Service Research Report. The classification is based on 617 sample stands. A total of 7 climax series, 30 habitat types, and 17 phases of habitat types are defined. Methods used to develop the habitat type classification are as described by Moir and Ludwig (1983) in these proceedings.

DESCRIPTION OF STUDY AREA

The study area encompasses the forest habitats of northern New Mexico and southern Colorado. Specifically, the forests studied occur in the Spanish Peaks and Wet Mountains of Colorado, and the San Juan Mountains and Sangre de Cristo Range of both Colorado and New Mexico. Forestlands included in this study are those that support any, or a combination, of the following coniferous tree species: *Picea engelmannii*, *Abies lasiocarpa*, *Pinus flexilis*, *Picea pungens*, *Abies concolor*, *Pseudotsuga menziesii*, and *Pinus ponderosa*.

Most of the data were collected within National Forests; however, a relatively small number of study plots were established on private and public lands outside National Forest boundaries. The sampling area ranged in elevation from about 1,800 m to 3,500 m and encompassed approximately four million hectares.

Mountain climates of the western United States have been described by Baker (1944) and

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Bradley (1976). The average mountain temperature lapse rate is 0.6 degrees C per 100 meters elevation increase. Generally, precipitation increases with elevation in the mountains. Within the study area, an average of 40 percent of the annual precipitation falls during the period of June through August.

Annual precipitation at 2,000 m elevation is approximately 400 mm throughout the study area, however, annual precipitation at about 4,000 m ranges from approximately 1,000 mm in the San Juan Mountains in Colorado, to 900 mm in the mountains of northern New Mexico, and to 600 mm in the Sangre de Cristo Range, Wet Mountains, and Spanish Peaks of Colorado. The higher total precipitation at high elevation in northern New Mexico relative to the mountains east of the Continental Divide in southern Colorado probably relates to the rain shadow effect of the massive San Juan Mountains in Colorado. Local conditions may produce precipitation much higher that that described here. For example, alpine rainforests in Colorado have been reported to receive in excess of 2,500 mm of precipitation during the summer (Ives 1942).

Snowfall accumulations vary from a maximum of 13 m in the San Juans of Colorado, to 8 m in the mountains of southcentral Colorado, and to 5 m in the mountains of northern New Mexico.

The number of frost-free days varies from less than 50 days in the Abies lasiocarpa series to over 120 days in the Pinus ponderosa series.

DESCRIPTIONS OF CLIMAX SERIES

Layser and Schubert (1979) provide general series descriptions for Southwestern forests. The descriptions given below represent refinement of their work for specific application to the northern New Mexico-southern Colorado study area.

Picea engelmannii Series

Geography

Picea engelmannii/Festuca thurberi is the only habitat type in the Picea engelmannii series. The series occurs predominately at upper timberline in the San Juan Mountains and Sangre de Cristo Range of Colorado.

Vegetation

Picea engelmannii and Pinus aristata typically co-dominate the overstory. However, in some stands one or the other of these species may be dominant. Abies lasiocarpa is a relatively minor component in this rather dry series. This supports Peet's (1978) suggestion that Picea engelmannii is more drought tolerant than Abies lasiocarpa.

Festuca thurberi is the most conspicuous understory component. Ribes montigenum, Achillea millefolium ssp. lanulosa, Arnica cordifolia, Chamerion angustifolia, Oreochrysum parryi, Polemonium pulcherrimum ssp. delicatum, Saxifraga bronchialis, Thalictrum fendleri, and Trifolium dasyphyllum are often present.

Physical Setting

The series is generally found on mid and upper slopes at elevations exceeding 3,200 m. It largely occurs at upper timberline but sometimes occurs elsewhere in the spruce-fir zone where tree growth is limited by drought. Soils vary from Cryorthents to Cryoborolls. The soils are characteristically skeletal, particularly in those situations where Pinus aristata is dominant.

Ecotones

This series ecotones with Festuca thurberi grasslands in drier situations and with the Abies lasiocarpa/Polemonium pulcherrimum habitat type on moister sites, e.g. northerly or less-windy exposures.

Comments

This series generally has a parkland appearance; with widely-spaced trees (occasionally clusters) interspersed with Festuca meadows. Owing to the strong representation of the highly palatable grass, Festuca thurberi, the grazing potential in this series is high. However, the generally remote locations of examples of this series make access difficult. This, combined with the typically steep slopes (generally in excess of 50 percent) reduce the practicality of utilization of this series for domestic grazing, except perhaps by sheep. Aesthetic attributes typically exceed economic ones and should be a prime consideration of management. Wildlife use, especially as summer range for elk, is an important characteristic of this series.

Fires are important within the series but seldom attain high enough intensity in the grass-dominated understory of these open forests to result in devastating crown-fires.

Areas where Pinus aristata is dominant or co-dominant generally represent drier, more-exposed, situations. In some locations, Festuca arizonica (a typically drier, lower elevation species than F. thurberi) occurs in association with F. thurberi.

Unlike situations within the Abies lasiocarpa/Polemonium pulcherrimum, the Abies lasiocarpa/Vaccinium, or the Abies lasiocarpa/MOSS habitat type where Pinus aristata forms a

minor seral component (Moir and Ludwig 1979), the more open forest situations in this series fail to give the more highly shade tolerant Picea engelmannii a competitive edge over Pinus aristata, and co-dominance of the two species, or, in some instances, sole occurrence of Pinus aristata is expressed. Layser and Schubert (1979) recognize a Pinus aristata series at high elevations. However, too few plots were takin in this study for such recognition.

Abies lasiocarpa Series

Geography

This series occurs throughout the highest elevations of the study area. A high degree of similarity exists among habitat types within this series throughout the Rocky Mountains. In fact, habitat types in the Abies lasiocarpa series exhibit many floristic similarities to Eurasian boreal forests (Kornas 1972). Forests in this series are extensive and are of considerable economic importance.

Vegetation

Most overstories exhibit co-dominance of Abies lasiocarpa and Picea engelmannii. However, young Abies typically outnumbers the less shade tolerant Picea; suggesting a tendency towards climax dominance by Abies (Pfister 1972). Abies has a furthur reproductive advantage in that both layering and reproduction by seed can occur while Picea reproduces strictly by seed (Hoffman and Alexander 1976). Picea is the more long-lived of the two species, however, so few pure Abies stands occur.

Following major disturbance, Populus tremuloides is a major seral species at the lower elevations of the series while upper elevations undergo direct successions to Picea and Abies. Lower elevations support Abies concolor and Pseudotsuga menziesii as seral or minor climax components.

Understories are highly varied. Maximal mesic conditions are achieved within this series, i.e., in the Abies lasiocarpa/Oxypolis fendleri habitat type. Within the wet forests, species lists commonly exceed 50 taxa in a given plot. Maximal cold conditions are also achieved within this series, in the Abies lasiocarpa/Polemonium pulcherrimum habitat type. The cold environment is substantiated by occurrence of floristic elements of the tundra often being present.

The single most characteristic understory component of most plant communities in the Abies lasiocarpa series is Vaccinium sp.. Havas (1971) suggests the distribution of Vaccinium sp. is limited by winter snow accumulation and persistance; snow being necessary to prevent dessication. The occurrence of Vaccinium sp. is thus indicative of cold, snowy environments characteristic of the Abies lasiocarpa series.

Physical Setting

At the highest elevations in the series (3,600 m), environments include cirques and other cold sites that retain snow cover late into summer, while lower elevations (2,700 m) are relatively warm. All landform types occur within the series, ranging from dry-exposed ridges (Abies lasiocarpa/MOSS habitat type) to wet-sheltered seep slopes (Abies lasiocarpa/Oxypolis fendleri habitat type). Soils are all in cryic great groups.

Ecotones

At its upper limit, the Abies lasiocarpa series borders alpine tundra. At its lower limit, the series ecotones to the Picea pungens series and herb-rich habitat types in the Abies concolor series on moist sites, and to herb-sparse Abies concolor habitats on dry sites.

Comments

Timber productivity is generally limited by the rigorous subalpine environment. Lower elevation sites have the highest timber potentials. Timber management at low elevations may favor either Picea engelmannii or Pseudotsuga menziesii. However, caution is necessary when managing for Pseudotsuga since frost-damage to regeneration may be severe. Wet habitats within the series require special care during timber harvests to prevent severe soil compaction, erosion, and conversion to sedge communities.

Heavy snow accumulations within the series make the preservation of watershed attributes a prime management directive. Also, the high aesthetic value of forests in the Abies lasiocarpa series make them favored by recreationists. The rate of recovery following major disturbance is slow (Pfister 1976). Thus, heavy timber harvests will impact recreational use for long periods.

Domestic forage production is generally poor except in localized valley bottom sites. Big game species utilize forests and adjacent non-forested communities as summer range.

Fire has played a major role in the ecology of portions of this series as evidenced by extensive Populus tremuloides stands. The large area of such seral communities and often scant conifer seed source makes alteration by fire evident for decades or even centuries (Steele et al. 1981). Snow avalances often occur at the upper elevations, and result in mosaics of varying stages of forest development.

Pinus flexilis Series

Geography

The *Pinus flexilis* series is of minor occurrence. *Pinus flexilis*/*Arctostaphylos uva-ursi* is the only habitat type defined in this series. The few samples were taken in the northern portion of the Sangre de Cristo Range in New Mexico and in the Wet Mountains of Colorado.

Vegetation

Pinus flexilis dominates the overstory in all stands, with *Pseudotsuga menziesii* and *Picea engelmannii* often subdominant. Understories are characterized by a conspicuous *Arctostaphylos uva-ursi* layer and the common occurrence of *Juniperus communis*. Herbaceous cover seldom exceeds trace amounts.

Physical Setting

Elevations cluster around 3,000 m and landforms are steep southerly upper slopes. Soils typically are skeletal and are Dystric Cryochrepts or Typic Cryorthents.

Ecotones

Most commonly, this series borders *Abies lasiocarpa*/*Vaccinium* habitat type on less-exposed and cooler environments within the same elevational zone. Ecotones to *Abies concolor*/SPARSE habitat type are also to be expected.

Comments

This series represents drier sites within the *Abies lasiocarpa*/*Vaccinium* zone. The exposed conditions favor snow movement rather than accumulation and the well-drained, skeletal soils do not provide suitable reservoirs to store adequate water to support *Abies* forest. Thus, the stands remain open, favoring the growth of "sun-loving" *Arctostaphylos uva-ursi*.

The relatively warm winter conditions and presence of big-game forage species in this type make it locally important winter range. The large seeds of *Pinus flexilis* provide food for birds and small mammals. Livestock use is very light due to difficult accessibility and low graminoid production. Timber productivity is low. Management would typically favor *Pseudotsuga* since *Pinus flexilis* is generally not an economically important species. High surface soil temperatures combined with low soil moisture may hamper regeneration following logging (Pfister et al. 1977).

Picea pungens Series

Geography

This series is restricted to cold-moist environments throughout the mixed conifer zone. Although widespread geographically, the areal extent of the *Picea pungens* series is relatively minor since the topo-edaphic features conducive to development of *Picea pungens*-dominated forests form a minor component of the landscape, e.g. sheltered slopes, frost pockets, perennially moist soils.

Vegetation

As a rule, overstories within the *Picea pungens* series are highly-mixed. In frost pockets, *Abies lasiocarpa* and *Picea engelmannii* occur as minor components of many stands (as in the *Picea pungens*/*Linnaea borealis* habitat type) while comparatively warm sites include *Pinus ponderosa* (as in the *Picea pungens*/*Festuca arizonica* habitat type). *Pseudotsuga menziesii* is typically co-dominant with *Picea pungens*, while *Abies concolor* is typically of secondary importance or absent. *Populus tremuloides* is the major tree species of seral stands.

The generally favorable moisture conditions result in rich species assemblages within this series. Moist sites are forby (dominant species include *Erigeron eximius*, *Artemesia franserioides*, *Fragaria americana*, *Oreochrysum parryi*, and *Thalictrum fendleri*), while drier sites exhibit a rich assortment of graminoids, e.g. *Carex foenea*, *Danthonia parryi*, *Festuca arizonica*, *Muhlenbergia montana*, and *Poa fendleriana*.

Physical Setting

Examples of this series are most frequently encountered on lower slopes protected from extreme sun and wind. Elevations range from 2,400 to 2,800 m. Soils are highly-varied taxonomically but are rarely lithic. Cryic soils are encountered in the *Picea pungens*/*Linnaea borealis* and occasionally in the *Picea pungens*/*Erigeron eximius* habitat type, while all other habitat types in the series are represented by frigid-udic soils.

Ecotones

Depending on elevation, the moist habitats in the *Picea pungens* series ecotone to herb-rich habitat types in the *Abies lasiocarpa* and *Abies concolor* series. Drier habitats in the series are adjacent to graminoid-dominated habitats in the *Abies concolor* series.

Comments

Pfister (1972) questioned the successional status of Picea pungens, suggesting that where Abies lasiocarpa or Abies concolor occur in association with P. pungens, P. pungens must be considered seral since it is the least shade tolerant of the three species. In this study, P. pungens was present and reproducing successfully even in those stands containing a complement of Abies sp.. Therefore, no evidence was found suggesting the eventual elimination of P. pungens from stands in the P. pungens series as defined here. This fact, and the finding that P. pungens is indicative of specific enviromental conditions, justify the recognition of a P. pungens climax series.

Heavy disturbance both by grazing and fire is widespread in this series. Careful evaluation of successional Populus tremuloides forests may suggest placement in this series depending on the presence or absence of Picea pungens regeneration.

Management options vary widely within this series. Timber productivity is moderate and Picea engelmannii, Pseudotsuga menziesii, and Pinus ponderosa may all be considered for management. Domestic forage production ranges from low (in the Picea pungens/Linnaea borealis habitat type) to high (in the Picea pungens/Festuca arizonica habitat type), and big game forage is good throughout the series. Snow accumulations are often significant and serve to heighten watershed opportunities within the series. Finally, scenic attributes are important since the characteristic lower slope positions of the series places it in view of many roads, trails, and campgrounds.

Abies concolor Series

Geography

The Abies concolor series occurs at mid-elevations and is the most widespread mixed conifer series. Only the Dolores Mesa country of the far-western San Juan Mountains of Colorado lack a representation of this series (since the area is outside the range of Abies concolor).

Vegetation

Overstories are highly-mixed, with seven coniferous species occurring together in some stands, i.e., Abies concolor, Abies lasiocarpa, Picea engelmannii, Picea pungens, Pinus flexilis, Pinus ponderosa, and Pseudotsuga menziesii. However, the presence and relative proportion of these species is dependent on moisture-temperature relationships. In all cases, successful reproduction of Abies concolor relative to other coniferous species is diagnostic of this series. Early seral communities are dominated by Populus tremuloides in mesic situations, and by Quercus gambelii on comparitively xeric sites.

Understories are also highly-variable. Among the diagnostic species, the coldest environments exhibit Vaccinium sp., while warm environments support abundant Festuca arizonica; dry sites feature Quercus gambelii, and moist sites favor Erigeron eximius. Shrub-rich, herb-rich, graminoid-rich, and stands having depauperate understories, i.e. Abies concolor/SPARSE habitat type, are all represented in this series. Understories may resemble those of the Pseudotsuga menziesii series on dry sites or the Abies lasiocarpa series on cold sites.

Physical Setting

Elevations range from 2,400 to 3,100 m. Settings vary from cold-moist sites having cryic soils to warm-dry sites having frigid-udic soils.

Ecotones

The Abies concolor series exhibits the most complex ecotonal relationships of any forested series in the study area (Layser and Schubert 1979). Upper elevations grade to the Abies lasiocarpa series, while cool-moist sites at the same elevation feature the Picea pungens series. Lower elevations support either the Pseudotsuga menziesii or Pinus ponderosa series (Pinus ponderosa occurring on the most xeric sites).

Comments

Management options are most highly varied within the Abies concolor series. Timber productivity may be high for Pseudotsuga menziesii in the Abies concolor/ Erigeron eximius habitat type. Grazing opportunities for domestic stock are maximized in the Abies concolor/Festuca arizonica habitat type. Big game utilization may be exceptionally high in the Abies concolor/Acer glabrum habitat type. Heavy snow accumulation will produce high water yields in the Abies concolor/Vaccinium habitat type. Varied topographical and biological conditions within the series add to the aesthetic attributes.

Basically, the Abies concolor series is ecologically similar to the Abies grandis series of the northern Rocky Mountains as described by Pfister et al. (1977) and Steele et al. (1981). Both the A. concolor and the A. grandis series lie between the drier Pseudotsuga menziesii series and the cooler Abies lasiocarpa series.

Fire is a major influence in maintaining many habitat types in this series. Abies concolor is relatively poorly-resistant to fire (Brown and Davis 1973) and is more highly shade tolerant than Pinus ponderosa and Pseudotsuga

menziesii (Baker 1950). Thus, many habitat types within the Abies concolor series are dominated by Pinus ponderosa and Pseudotsuga menziesii in mid-seral stages, with Abies steadily gaining dominance as succession proceeds.

Pseudotsuga menziesii Series

Geography

The Pseudotsuga menziesii series is relatively minor in the study area and is represented by only two habitat types: Pseudotsuga/Festuca arizonica and Pseudotsuga/Quercus gambelii.

Vegetation

In addition to Pseudotsuga, Pinus ponderosa is often a dominant feature of the overstory. Warmer sites within the series may also feature Juniperus scopulorum and Pinus edulis while relativey cool envirionments include Pinus flexilis. At high elevations, Pinus aristata dominates or co-dominates. Abies concolor is absent or minor. Early successional forests are typically dominated by either Populus tremuloides (in the Pseudotsuga/Festuca arizonica habitat type) or Quercus gambelii (in the Pseudotsuga/Quercus habitat type).

Understories vary from grassy Festuca arizonica-dominated situations to shrubby Quercus gambelii-dominated situations.

Physical Setting

Steep slopes characterize this series. Elevations range from 2,000 to 3,000 m. Soils are frigid and generally have udic moisture regimes at higher elevations and ustic moisture regimes at lower elevations.

Ecotones

Warm-dry sites favor the Pinus ponderosa series while ecotones in moist environments are with the Abies concolor series.

Comments

Pseudotsuga has the greatest ecological amplitude of any coniferous species in the study area. In the northern Rocky Mountains, Rehfeldt (1974) demonstrated substantial genetic variation among Pseudotsuga populations from contrasting habitats. This genetic diversity contributes to the broad ecological amplitude. However, Pseudotsuga is lower in shade tolerance relative to Abies sp. and thus is not considered climax in Abies sp. stands in which it cooccurs. Thus, the Pseudotsuga series is relatively minor in areal extent since few stands where Pseudotsuga is important are not co-dominated by more shade-tolerant species.

The series generally does not contain productive timberlands. Forage production for livestock is high in the Festuca arizonica-dominated forests.

Pinus ponderosa Series

Geography

The Pinus ponderosa series is found throughout the low elevations of the study area. Unlike the broad geographical similarities within the Abies lasiocarpa series within the Rocky Mountains, relatively few similarities exist within the P. ponderosa series on a regional basis.

Vegetation

Pinus ponderosa is the least shade tolerant tree of the seven species considered in this study. Therefore, only those stands where P. ponderosa dominates the regeneration lie within the P. pondersosa series. In moister environments, Pseudotsuga menziesii may occur in minor amounts, and in warm-dry situations Pinus edulis and Juniperus scopulorum are important. Quercus gambelii is a common seral tree; although in areas lacking Quercus, succession to P. ponderosa is direct.

Dry-site understories are similar to adjacent non-forest communities. Grasses such as Bouteloua gracilis, Schizachyrium scoparium, Poa fendleriana, and Muhlenbergia montana are characteristic of such situations. Moist-site understories are similar to the Pseudotsuga menziesii series and also similar to drier habitats in the Abies concolor series. In these cases, Arctostaphylos uva-ursi, Quercus gambelii, and Festuca arizonica may be important.

Physical Setting

The series may be found on any slope or aspect between the elevational range of 1,800 to 2,900 m. Soils are generally frigid and ustic.

Ecotones

The first forest type encountered above low-elevation grasslands and pinyon-juniper woodlands is the Pinus ponderosa series. Except for Pinus edulis and Juniperus sp., P. ponderosa is the most drought resistant of the conifers in the study area. Following P. ponderosa in drought resistance is Pseudotsuga menziesii (Pharis 1966). Higher elevational ecotones are with the P. menziesii series. In some mesic

situations, ecotones to the Abies concolor series occur.

Comments

Surface fires are a natural component of the P. ponderosa cover type and served to maintain open park-like stands throughout much of the series (Cooper 1960). However, the advent of modern fire suppression has resulted in the establishment of dense patches of young trees in many areas. The added shade and needle accumulation under such patches hinders development of herbaceous understories (Daubenmire and Daubenmire 1968). In such situations, habitat type identification may be difficult due to low coverage or absence of indicator species. Furthermore, fire exclusion may favor reproduction of more shade tolerant species, e.g. Pseudotsuga menziesii, Abies concolor, that normally would not occur given a natural fire regime. Hence, presence of Pseudotsuga or Abies beneath a P. ponderosa overstory may not always indicate sites outside the P. ponderosa series if fire exclusion programs are in operation.

Pristine forests are more rare in the P. ponderosa series than in the other forest series. Grazing damage has been particularly severe and has resulted in conversions of native grass-rich understories to weed-rich understories. Dominance of such species as Hymenoxys sp., Taraxacum officinale, Xanthocephalum sarothrae, Bromus tectorum, and Poa pratensis indicate overgrazing. Such pervasive alteration of the understory adds to the difficulty in ascertaining the correct habitat type. In some cases, the alteration of soil and vegetation may be so severe that the potential of such habitats to support climax plant communities no longer exists.

Similarly, the ease of access of most habitats in the P. ponderosa series and the desirable properties of P. ponderosa lumber has resulted in heavy timber harvests throughout the series. The alteration of the tree canopy further adds to the difficulty in inferring tree stucture at climax.

In general, forests in the P. ponderosa series represent the least-productive timberlands. Regeneration is generally difficult since favorable seedcrops, favorable soil moisture, and open sites seldom coincide. Heavy grass cover and heavy livestock grazing severely impede regeneration. Since many P. ponderosa habitats are graminoid-rich, livestock grazing is a prime management directive. Recovery from overgrazing may require decades. Abundant big game browse is found in shrubby habitat types.

HABITAT TYPE RELATIONSHIPS

The 30 non-riparian forest habitat types of northern New Mexico and southern Colorado and their phases are listed in table 1. Generally, the order of habitat types in table 1 is from cold-moist to warm-dry.

Table 1.--Listing of northern New Mexico-southern Colorado forest habitat types.

Picea engelmannii Series
1. Picea engelmannii/Festuca thurberi

Abies lasiocarpa Series
2. Abies lasiocarpa/Polemonium pulcherrimum
   - Picea engelmannii phase
   - Abies lasiocarpa phase
3. Abies lasiocarpa/Oxypolis fendleri
4. Abies lasiocarpa/Vaccinium
5. Abies lasiocarpa/MOSS
6. Abies lasiocarpa/Linnaea borealis
   - Linnaea borealis phase
   - Rubus parviflorus phase
7. Abies lasiocarpa/Erigeron eximius
   - Erigeron eximius phase
   - Rubus parviflorus phase

Pinus flexilis Series
8. Pinus flexilis/Arctostaphylos uva-ursi

Picea pungens Series
9. Picea pungens/Linnaea borealis
10. Picea pungens/Erigeron eximius
11. Picea pungens/Carex foenea
12. Picea pungens/Arctostaphylos uva-ursi
13. Picea pungens/Festuca arizonica

Abies concolor Series
14. Abies concolor/Vaccinium
15. Abies concolor/Erigeron eximius
16. Abies concolor/Acer glabrum
17. Abies concolor/SPARSE
18. Abies concolor/Arctostaphylos uva-ursi
19. Abies concolor/Festuca arizonica
20. Abies concolor/Quercus gambelii

Pseudotsuga menziesii Series
21. Pseudotsuga menziesii/Festuca arizonica
   - Pinus aristata phase
   - Pseudotsuga menziesii phase
22. Pseudotsuga menziesii/Quercus gambelii
   - Festuca arizonica phase
   - Quercus gambelii phase

Pinus ponderosa Series
23. Pinus ponderosa/Arctostaphylos uva-ursi
24. Pinus ponderosa/Festuca arizonica
   - Danthonia parryi phase
   - Festuca arizonica phase
25. Pinus ponderosa/Quercus gambelii
   - Festuca arizonica phase
   - Quercus gambelii phase
26. Pinus ponderosa/Muhlenbergia montana
27. Pinus ponderosa/P. edulis/Quercus gambelii
28. Pinus ponderosa/Bouteloua gracilis
   - Festuca arizonica phase
   - Schizachyrium scoparium phase
   - Bouteloua gracilis phase
29. Pinus ponderosa/Quercus grisea
30. Pinus ponderosa/Oryzopsis hymenoides

The relationship of major habitat types to elevation and a topographic moisture gradient is shown in figure 1. The xeric end of the moisture gradient represents southerly exposures and dry ridges while the mesic end represents northerly aspects and protected slopes, e.g., lower slopes. The wet portion of the moisture gradient includes streamsides, bogs, and seep slopes.

Figure 1 presents an approximation of the actual relationships between habitat types. The diagram depicts general relationships between habitat types as they are currently understood. Absolute relationships should not be inferred from this graph. Instead the graph is useful in suggesting the central concepts of given habitat types. For example, the graph indicates that within the *Pinus ponderosa* series, *Festuca arizonica*-dominated understories generally occur in more mesic situations relative to *Quercus gambelii*-dominated understories.

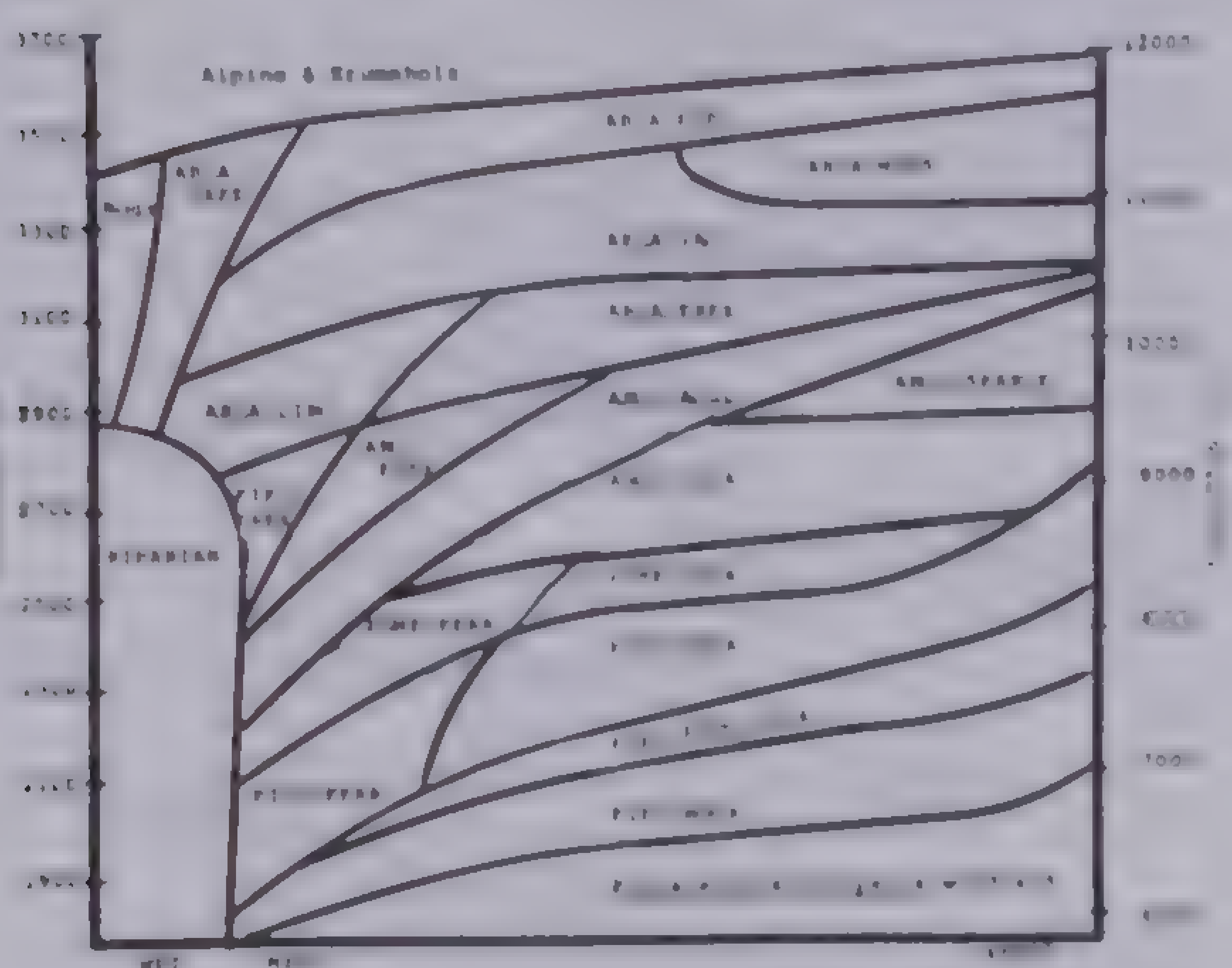

Figure 1.—Mosaic diagram of major habitat types of northern New Mexico and southern Colorado (codes used are the first two letters of genera and specific epithets given in table 1).

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A Habitat Type Classification of the Pinyon-Juniper Woodlands of the Lincoln National Forest, New Mexico[1]

Kathryn L. Kennedy[2]

Six pinyon-juniper habitat types (HT's) are described, based on overstory and understory characteristics of plots sampled in the Lincoln National Forest of New Mexico. The habitat type approach appears to be appropriate for the area but is more time consuming and difficult due to pervasive disturbance and lack of information about succession processes.

INTRODUCTION

Pinyon-juniper (P-J) woodlands cover approximately 60 million acres in the U.S. (Little, 1977). In New Mexico around 26% of the state is P-J (West et. al, 1975). These woodlands are subjected to a variety of demands, and are economically and socially important. P-J occurs upon significant watershed areas, and supplies grazing land, recreation areas, fuelwood, fenceposts, railroad ties, Christmas trees pine nuts, and wildlife habitat (Aldon and Loring, 1977).

Too little is known about the variation within P-J and its sensitivity. Most existing literature examining P-J lacks quantitative data, giving only general descriptions that are not very useful on the local level (Layser and Schubert, 1979). In New Mexico information is particularly scarce.

Investigation of P-J and classification into recognizable, ecologically distinct habitat types would assist management efforts and provide a basis for organization and evaluation of research. The habitat type approach seems most desirable, as it would be compatible with other timber classifications and have immediate applicability (Pfister and Arno, 1980).

The habitat type method requires that data be collected in mature or near climax plant communities. This has caused concern about the suitability of the approach, as P-J is known to be pervasively disturbed. Man has used these woodlands extensively, in some areas since prehistoric times (Betancourt and Van DeVender, 1981).

In an attempt at habitat type classification, an extensive investigation of the Great Basin P-J was conducted by Richard Meeuwig, Bob Murray, Steve Cooper and Associates. The attempt was unsuccessful due to disturbance, lack of information on succession processes, and the depauperate nature of the understory in climax and late seral stands.

Much of the P-J in New Mexico is believed to be in better condition than that of the Great Basin, and this study was undertaken, in part, to see if habitat type methods might be successful.

THE STUDY AREA

The Lincoln National Forest and adjacent lands were selected for study, including the Jicarilla, Capitan, Sacramento, and Guadalupe mountains. This region is predominately considered the Sacramento section of the Basin and Range physiographic province. Soils in the region are highly variable, influenced mostly by erosional versus depostional positions in the landscape(cf. Moir 1979), as well as variations in parent materials ranging from calcareous to acidic mineralogies.

Mean annual precipitation is about 16 inches/year (41 cm/yr.) and more than half the year's total moisture occurs in July, August, and September.

This area has a long record of use by man. Prehistoric Indians used the woodlands extensively, and all study areas have evidence of their activity. European man's greatest use has been for grazing and fencepost cutting, dating back to the late 1800's. Placer mining, small scale orchard and bean farming operations, and range and watershed improvement projects have cleared or disturbed some areas. As a result of these activities, as well as fires of various intensities, much of the P-J region exists today in seral condition.

METHODS

My procedures were essentially those of habitat type classification as described by Moir and Ludwig (1979) and Pfister and Arno (1980) and discussed by Ludwig and Moir in this Proceedings.

A profile of land use, disturbances and characteristic features of the area was compiled before field work started. Information about fires, cut-

[1]Paper presented at the Workshop on Southwestern Habitat Types. [Albuquerque, N.M. April 6-8, 1983].

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ting, grazing, watershed projects and geology was collected and noted on maps.

A survey was then done along roadsides and trails, locating and sampling suitable stands. Climax conditions in the classical sense were not always obtainable. Daubenmire (1968) noted that this is frequently the case, but that enough information to surmise the potential climax could be obtained by sampling mature stands showing strong evidence of regeneration of the tree species present. He stated that following major disturbances herb and shrub layers reach equilibrium before tree layers. There have been questions, however, about how long grazing induced "zootic disclimax" conditions might persist after livestock intensity is reduced, and confuse the estimation of potential climax.

Criteria for stand eligibility attempted to insure sampling of mature stands and minimize the risk of unrecognized grazing induced "disclimax" conditions. Eligible stands were required to have pinyon (Pinus edulis) as a dominant or codominant climax species. Stands sampled were those with large full crowned trees older than 75 years (determined by increment coring larger pinyon trees), a varied tree age structure, and adequate numbers of seedlings to insure replacement of mature trees. Stands were rejected if cutting was judged severe enough to distort the tree population structure or affect overstory-understory relationships. Composition and coverage of the understory was examined. Grazing influence was considered minimal if there was ample coverage of a variety of palatable forage and browse species. Representation of cool season grasses was particularly important. Selected sites also had to exhibit a low proportion of "weedy" species, often a number of herbaceous or suffrutescent composites. Land use history and the proximity of watering locations were helpful guides in searching for relatively livestock-free areas. Soils and geology of the plots were not investigated in this study. The U.S. Forest Service Terrestrial Ecosystem Survey discusses the soils of the P-J woodlands in the Sacramento Mountains in relation to those of other vegetation subseries.

Some modifications of the data collection methods of Pfister and Arno (1980) were made to adjust for differences in size range and growth forms of tree species. For elaboration of field techniques see Kennedy (1983).

Data were analyzed using the specific successive approximation techniques of Moir and Ludwig (1979). Computer programs developed by Dr. John Ludwig were used for stand table synthesis and mathematical evaluation techniques. Initially, plots were visually grouped based on similarities in dominant tree species present. Releve stand tables were then generated by computer, and tabular comparisons were made, examining major species of understory and overstory. Cluster and ordination analyses were also done (Kennedy, 1983).

The grouping of plots obtained by each analyses was examined, and the most consistent and ecologically reasonable groups were selected. Final stand tables were constructed grouping plots into habitat types based on both mathematically demonstrable similarity and ecological interpretation based on field observations (Appendix Table 1).

RESULTS

Thirtynine plots were grouped into six HT's given in Table 1. A description of each follows. For elaboration on sensitivity, land management implications, etc. see Kennedy (1983). Tabular summaries of habitat type data, keys, and a species list are in the appendix.

Description of Habitat Types

1. Pinus edulis-Juniperis monosperma/Cercocarpus montanus/Andropogon gerardii HT

Diagnostic vegetation. Light (less than 100 stems/ha) to moderate (more than 300 stems/ha) regeneration of Pinus edulis and Juniperus monosperma with a poorly developed understory dominated by Cercocarpus montanus with a cover ranging from 3% to 6% and occasionally Rhus trilobata, ranging from a trace to 5%.

Herbaceous layer cover averages less than 40% and is dominated by Andropogon gerardi (mean 4%), Bouteloua gracilis (mean 4%), and Bouteloua curtipendula (mean 3%).

Occasionally a sparse understory exists where the shrub layer is not represented.

Geography. Guadalupe, Jicarrilla and Sacramento Mountains.

Topography. Moderate to steep slopes from 5200 ft. (1585m) to 7600 ft. (2316m) and southerly or westerly exposures. This HT occurs on rocky (30-70% surface cover with cobbles) sites positioned on the mid to upper third of slopes.

Discussion. This HT is restricted to localized rocky points and outcroppings. Understory cover decreases with increasing slope. Tree density is relatively low. Ecotones occur with grasslands or oak brush at lower elevations. The dry, rocky nature of these sites and sparse, slow growing understory makes them unable to sustain much grazing.

TABLE 1. PINYON-JUNIPER HABITAT TYPES OF THE LINCOLN NATIONAL FOREST.

Habitat Type	Abbreviation[1]	# of Plots
PINYON-JUNIPER SERIES		
1. Pinus edulis-Juniperus monosperma/ Cercocarpus montanus/Andropogon gerardii HT	PIED-JUMO/CEMO/ANGE HT	5
2. Pinus edulis-Juniperus monosperma/ Muhlenbergia pauciflora HT	PIED-JUMO/MUPA HT	14
3. Pinus edulis-Juniperus monosperma/ Stipa columbiana HT	PIED-JUMO/STCO HT	4
4. Pinus edulis-Juniperus monosperma/ Bouteloua gracilis HT	PIED-JUMO/BOGR HT	8
5. Pinus edulis-Juniperus deppeana/ Bouteloua gracilis HT	PIED-JUDE/BOGR HT	4
6. Pinus edulis-Juniperus deppeana/ Muhlenbergia dubia HT	PIED-JUDE/MUDU HT	4

[1]Abbreviations use four letter computer codes and conform to the style of previous USDA Forest Service habitat type classifications.

2. Pinus edulis-Juniperus monosperma/Muhlenbergia pauciflora HT.

Diagnostic vegetation. Light to moderate Pinus edulis and Juniperus monosperma regeneration. Crown dominance usually by Juniperus monosperma. Muhlenbergia pauciflora is dominant in the understory (cover 2-35%), occurring with Bouteloua gracilis, Bouteloua curtipendula, and Eragrostis intermedia. Lycris phleoides is frequently present. Quercus undulata (mean cover 7%) and Rhus trilobata (mean cover 4%) are consistently present shrubs.

Geography. Plots were situated in the Capitan and Sacramento Mountains. This type was observed in other areas as well.

Topography. Gentle to moderate slopes from 6200 ft (1889m) to 7300 ft. (2225m), usually on southerly exposures. Predominately occurs on upper slopes and redges.

Discussion. This HT occurs extensively throughout the Lincoln National Forest. It represents the drier end of the spectrum of grassland understory HTs sampled. As rockiness and slope increases an ecotone into oak brush occurs. Ecotones occur with the Pinus edulis-Juniperus Monosperma/Bouteloua gracilis HT on more mesic exposures or flatter land forms.

Frequently, plots included in this HT had a considerably increased shrub cover (12-27%), predominately of the Quercus undulata complex. These shrubbier plots occurred on the steeper slopes noted for the habitat type, and often were in mid slope positions. Such sites were not found to occur naturally in sufficient quantity to elevate this association to phase or habitat type status.

In many areas were disturbances have occurred there is a great increase in the cover of Quercus undulata (70-90%). This may be related to soil erosion, creating sites favoring oak brush instead of grassy understory.

3. Pinus edulis-Juniperus monosperma/Stipa columbiana HT.

Diagnostic vegetation. Moderate to very heavy regeneration of Pinus edulis. Light to moderate regeneration of Juniperus monosperma. Stipa columbiana is the dominant understory plant (6-18%) occuring in a grassy understory with Bouteloua gracilis Bouteloua curtipendula. The presence of a distinct litter layer is noteworthy. (fig. 1).

Geography. Jicarilla and Sacramento mountains.

Topography. Upper regions of gentle (mean 11%) slopes from 6800 ft. (2072m) to 7300 ft. (2225m) elevation. Sites have various exposures, but exhibit a characteristically low rockiness.

Discussion. A more mesic Pinus edulis-Juniperus monosperma HT. Not extensive. Site quality for Pinus edulis appears good, and it is conspicuously dominant. An extensive litter layer is characteristic. Soils appear to be deeper here, plot surfaces are not rocky and slopes are gentle. Ecotones occur with the Pinus edulis-Juniperus monosperma/Bouteloua gracilis HT at lower elevations and drier sites.

This HT may well be maintained by relatively frequent, light ground fires. Moir (1982) found junipers less fire resistant than Mexican pinyon (Pinus cembroides) in the Chisos Mountains, and no evidence of extensive crown fires. Localized low intensity fires appear to be common, possibly even an essential part of ecosystem dynamics in pinyon-juniper woodlands (Ahlstrand 1979, Moir 1982). Workers (Moir, Ludwig, personal communication) have found Stipa columbiana to be a successional species after fire in higher elevation vegetation zones. Stipa columbiana appears to have a more permanent role in this community, though it was also observed in areas with fairly recent burns.

Figure 1.--PIED-JUMO/STCO HT

4. Pinus edulis-Juniperus monosperma/Bouteloua gracilis HT.

Diagnostic vegetation. Moderate and sometimes heavy regeneration of Pinus edulis and Juniperus monosperma. Bouteloua gracilis is the dominant species (5-15%) in a well developed understory (mean cover 36%) including Bouteloua curtipendula, Sitanion hystrix, and frequently Koeleria pyrimidata. Quercus undulata is usually present in small quantities.

Geography. This HT is widespread throughout the Lincoln National Forest.

Topography. This HT occurs predominantly on the tops and upper slopes of gently rolling hills. It ranges from 5100 ft. (1554m) to 7600 ft. (2316m) and is nearly always found on cooler, moister northerly and easterly slopes.

Discussion. This HT is the most widespread HT found on the Lincoln National Forest. Ecotones occur with the Pinus edulis-Juniperus monosperma/Muhlenbergia pauciflora HT at lower elevation and steeper sites. At higher elevations ecotones occur with Pinus edulis-Juniperus deppeana/Bouteloua gracilis HT in a few areas.

Fire, mining disturbance, and activity aimed at woodland conversion to grassland has resulted in extremely thick, brushy Quercus undulatus understories (greater than 70% cover) in many areas.

5. Pinus edulis-Juniperus deppeana/Bouteloua gracilis HT.

Diagnostic vegetation. Moderate regeneration of Pinus edulis and light to moderate regeneration of Juniperus deppeana. Light regeneration of Juniperus monosperma. The understory dominant is Bouteloua gracilis, present in unusually high quantities (20-37%). Lycuris phleodies and Piptochaetium fimbriatum commonly occur. No significant shrub layer exists.

Geography. Capitan and Sacramento Mountains.

Topography. Gentle slopes and flat lands from 6400 ft. (1959m) to 7200 ft. (2195m). There is a characteristic lack of rockiness (less than 20%). Various exposures and slope positions are represented.

Discussion. This HT is similar to the widespread Pinus edulis-Juniperus monosperma/ Bouteloua gracilis HT, but it is not as extensive in the Lincoln National Forest. Ecotones between them have been observed in a few areas. This HT is found on higher elevation, gently undulating land forms. It probably represents a more mesic condition, as demonstrated by its percentage cover (46%), highest of any habitat type characterized, and also by the presence of species like Piptochaetium fimbriatum and Juniperus deppeana.

6. Pinus edulis-Juniperus deppeana/Muhlenbergia dubia HT.

Diagnostic vegetation. Moderate to heavy regeneration of Juniperus deppeana. Dominant understory plant is Muhlenbergia duba (cover range 2-44%) , which occurs with other grasses such as Piptochaetium fimbriatum, Muhlenbergia emeryslei, Bouteloua curtipendula, and Bouteloua curtipendula. and Bouteloua gracilis. (fig. 2). Herbaceous understory averages 47%. There is a sparse shrub layer composed predominately of of Quercus undulata (mean cover 5%) with Rhus trilobata (mean cover 2%).

Geography. Guadalupe and Sacramento Mountains.

Topography. Occurs from 6000 ft. (1828.8m) to 7300 ft. (2225m) on moderate slopes of predominately southeastern exposures. Characteristically found on slightly to moderately rocky sites (10-30%).

Discussion. This HT is one of the highest elevation, most mesic HT North facing slopes opposite are often Ponderosa stands. Ecotones occur with Pinus edulis-Juniperus deppeana/

Figure 2.--PIED-JUDE/MUDU HT

Bouteloua gracilis Ht on lower elevation and flatter land forms.

Additional Habitat types

The remainder of the 52 plots sampled included some identifiable vegetation associations which did not have sufficient plot data to designate as HT's. Hopefully, more data will be obtained to clarify these.

One such association is in Pinus edulis-Juniperus deppeana stands that contain Arbutus xalapensis (Madrone) trees with a Muhlebergia dubia understory (plots 28 and 33). This association is restricted to the Guadalupe Mountains and perhaps to a few sites in the Capitan Mountains. Northington and Burgess (1975) note a similar association in the Guadalupe Mountains National park. The Arbutus is endangered, heavily browsed by cattle, and the association survives today only in remote areas. Nevertheless the assemblage has recognizable environmental characteristics (mesic sites, medium rockiness, moderate slopes of canyon lands), and its former extent is still traceable in the area through the presence of small (usually heavily browsed) Arbutus shrubs on grazed lands. Its development is probably related to edaphic conditions in the area.

The role of shrubby forms of Quercus undulata in the naturally occurring vegetation in the Lincoln National Forest may eventually be found to merit HT status, either in assemblage with Pinyons and Junipers or alone. Large areas of the forest have significant coverage with Quercus undulata, but most of these areas had sustained severe fire or man made erosional (mining, overgrazing, etc.) disturbances. Plots with significant amount of Quercus undulata were found in apparently natural situations (steep slopes and rocky outcroppings), but too few were located to establish a HT.

A third suspected HT has a good representation of Quercus grisea trees in association with

Pinus edulis and *Juniperus deppeana* (plots 25 and 26). These plots were from the White Mountain wilderness and the assemblage was also seen in the Guadalupe Mountains. Northington and Burgess (1975) noted the occurrence of *Q. grisea* and stated they they felt it was probably more xeric than sites with *Q. undulata*. Moir (1982) described a *Pinus cembroides/Muhlenbergia emersley* HT in the Chisos Mountains with significant amounts of *Q. grisea*.

Another occasionally observed but undersampled situation (plots 49 and 50) was an assemblage of *Pinus edulis* and *Juniperus deppeana* in an essentially closed canopy with extremely sparse understory (less than 15% total cover). This condition was observed on more mesic sites, and a well developed litter layer (4 cm in depth) was consistently present. Alexander (1983) notes a similar situation in his habitat classification of the Lincoln National Forest.

Summary and Conclusions

This investigation of 52 plots in the pinyon-juniper woodlands of the Lincoln National Forest has produced a HT classification based on understory characteristics that is compatible with USFS HT classifications for other forest zones. A HT approach appears to be appropriate for classification in the area. Habitat typing in pinyon-juniper woodlands is a more time consuming process and requires a greater effort than habitat typing in more mesic forest zones. Due to pervasive disturbance, stands acceptable for sampling are difficult to locate. In some areas disturbance is so severe that vegetation potential of the site has undoubtedly changed. Greater success could be expected if more sampling were done further from roadways.

Lack of information about successional processes in pinyon-juniper created some difficulties in site assessments, particularly with shrubby oak communities.

The classification presents six habitat types. Four additional probable habitat types are discussed. No juniper series such as that of Layser and Schubert (1979) was found. Juniper stands in the study area appear to be relatively young and even aged, or are so restricted in areal extent that they constitute more of an ecotone than a distinct vegetation zone. Pure juniper stands did not appear to be mature reproducing vegetation units, though inability to deter mine age of junipers in the field made assessment extremely difficult.

Keys have been prepared to aid in field identification of habitat types (see appendix). These keys are intended as field guide to mature stands and are not necessarily applicable to disturbed areas. However, with field experience in the habitat types, the potential of most areas can be readily identified even with some disburbance.

Habitat types did not sort along any particular environmental variable that could be considered determinant, though there was a close correspondence with average elevation. These habitat types appear to be a response to the overall xeric or mesic nature of the site rather than to any single environmental variable. Tree density and percent cover generally tend to increase as conditions become cooler and/or wetter (Table 2). Special diversity also tended to increase with more mesic conditions. *Pinus edulis-Juniperus Deppeana* HT's appear to require more mesic conditions than do *Pinus edulis-Juniperus monosperma* HT's.

The classification is based on site dynamics and the natural vegetation response to environmental characteristics, so the habitat types should be useful as a guide in baseline ecological studies and in applied investigations for land use planning. It would be of limited use to vegetation mappers and plant geographers who need to describe present vegetation status rather than trends at maturity.

Modifications and refinements of this classification are expected as investigation continues. Field validation of the classification is necessary and input from other investigators will be helpful.

Table 2.--Estimated alignment of plots along a xeric to mesic environmental gradient.

Xeric	Habitat Type	Average Elev.Ft.	Understory %	Tree Density Avg. Stems/Plot
	PIED-JUMO/CEMO AMLE	[illegible]	4.	36
	PIED-JUMO/MUPA	6470	33	63
	PIED-JUMO/BOGR	6678	36	123
	PIED-JUMO/STCD	6977	37	163
	PIED-JUDE/BOGR	6739	46	65
[illegible]	PIED-JUDE/MUMO	[illegible]	4?	1?5

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Table A-1. Final stand table showing plots grouped into habitat types. Data entries for tree species are number of stems greater than 1 dm. per plot. Data entries for understory species are percent cover.

PLOTS AND HABITAT TYPES

SPECIES CODE	PIED-JUMO/ CEMO/ANGE					PIED-JUMO/MUPA													
	34	48	32	36	35	21	45	9	7	10	12	38	15	4	14	8	11	6	5
PIED-YNG REGEN[1]	4	13	9	0	24	0	31	5	6	3	10	42	0	26	5	2	1	1	4
PIED-ADV REGEN	22	14	29	0	6	2	27	11	7	19	10	10	2	51	6	13	1	8	6
PIED-MATURE	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	1	0
JUDE-YNG REGEN	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUDE-ADV REGEN	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUDE-MATURE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUMO-YNG REGEN	0	4	0	32	13	9	12	5	21	1	19	45	9	13	27	20	14	9	30
JUMO-ADV REGEN	0	0	0	0	1	10	14	10	21	27	3	15	10	10	6	31	16	20	19
JUMO-MATURE	0	0	0	0	1	0	0	4	6	0	0	0	0	0	1	6	5	10	6
QUMU-YNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
QUMU-ADV	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
QUGR-REGEN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
QUGR-MATURE	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BOGR	4	0	1	5	10	1	0	0	2	6	0	14	1	0	6	0	5	8	6
BOCU	2	2	3	5	0	6	0	2	3	7	6	13	6	7	8	3	3	1	7
BOHI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
MUPA	4	1	0	0	0	0	5	5	12	11	35	6	0	24	15	7	2	6	4
MUDU	0	0	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUEM	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LYPH	1	0	0	0	0	3	0	0	0	0	0	3	3	0	0	3	5	4	4
PIPI	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
KOCR	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ERIN	0	0	0	0	0	1	0	3	2	0	0	3	1	0	1	4	5	1	5
SIHI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANSC	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANGE	1	0	10	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PABU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
QUUN	0	3	0	0	0	0	0	27	16	12	25	4	0	1	3	8	7	1	3
CEMO	6	3	4	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RHTR	0	4	3	5	0	3	0	7	12	8	1	2	3	1	1	7	4	2	2
YUBA	0	1	0	2	6	3	2	0	0	0	0	0	3	0	0	0	0	0	0

SPECIES CODE	PIED-JUMO/ STCO				PIED-JUMO/BOGR								PIED-JUDE/ BOGR				PIED-JUDE/ MUDU			
	24	40	41	22	20	37	19	18	16	43	17	23	3	13	1	2	31	42	44	46
PIED-YNG REGEN[1]	103	16	169	232	9	20	46	30	1	59	81	12	36	14	33	3	8	41	47	62
PIED-ADV REGEN	41	22	37	117	21	7	19	40	17	7	25	37	17	21	3	1	10	56	30	37
PIED-MATURE	1	2	0	1	0	1	4	1	1	2	1	1	1	0	2	0	0	1	0	1
JUDE-YNG REGEN	0	0	0	0	0	0	0	0	0	1	2	0	5	1	14	3	10	13	15	23
JUDE-ADV REGEN	0	0	0	0	0	0	0	0	0	1	16	1	8	0	3	34	20	3	13	6
JUDE-MATURE	0	0	0	0	0	0	0	0	0	0	1	1	1	0	2	1	1	0	2	3
JUMO-YNG REGEN	13	25	24	36	9	21	59	18	3	3	16	7	0	9	23	4	0	3	0	0
JUMO-ADV REGEN	4	18	7	19	36	23	12	11	13	6	16	9	3	12	3	1	1	0	0	0
JUMO-MATURE	3	6	0	1	1	0	1	2	2	1	1	1	0	1	2	0	0	0	0	0
QUMU-YNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
QUMU-ADV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
QUGR-REGEN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
QUGR-MATURE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BOGR	7	9	1	3	8	8	13	15	5	0	8	11	34	37	20	24	3	2	2	4
BOCU	0	4	5	1	7	23	1	7	1	4	0	0	0	5	9	0	2	2	4	1
BOHI	1	0	0	0	1	2	3	0	0	0	0	2	0	0	0	0	1	0	0	0
MUPA	0	10	0	0	0	0	0	0	3	0	0	0	0	5	0	0	0	2	0	2
MUDU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	10	44
MUEM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	9	0
LYPH	0	2	0	0	2	0	0	0	0	0	2	0	0	0	0	1	1	0	1	0
PIPI	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	17	2	0	12	3
KOCR	1	1	0	0	0	0	0	6	6	4	4	3	12	0	0	0	0	0	0	0
ERIN	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SIHI	2	3	1	2	0	0	1	2	3	1	3	4	0	0	0	0	0	1	1	0
STCO	18	12	22	6	5	0	0	0	2	3	0	0	0	0	2	0	0	0	0	0
ANSC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
ANGE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
PABU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
QUUN	0	2	3	4	2	0	0	4	2	0	0	2	0	0	0	0	8	2	6	4
CEMO	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
RHTR	0	0	2	1	0	0	0	0	1	0	0	0	0	1	0	0	4	1	2	0
YUBA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

[1] YNG REGEN= Young Regeneration= stems < 2 in. d.b.h.; ADV REGEN= Advanced Regeneration= stems 2-10 in. d.b.h.;MATURE=>10 in. d.b.h.

Species List--Pinyon-Juniper Woodlands of the Lincoln National Forest, with Computer Letter Code

I. Trees

ARXA	*Arbutua xalapensis* H.B.K.
JUDE	*Juniperus deppeana* Steud.
PIED	*Pinus edulis* Engelm.
PIPO	*Pinus ponderosa* Laws.
PSME	*Pseudotsuga menziesii* (Mirbi) Franco.
QUGR	*Quercus grisea* Liebm.
QUMU	*Quercus Muehlenbergii* Engelm.

II. Shrubs

AGNE	*Agave neomexicana* Woot. & Standl.
ARXA	*Arbutus xalapensis* H.B.K.
BEHA	*Berberis haematocarpa* Wooton.
CEGR	*Ceanothus greggii* Gray.
CEMO	*Cercocarpus montanus* (Wats) F.L. Martin.
FERU	*Fendlera rupicola* Gray.
GAOV	*Garrya ovata* Benth.
LYCIUM	*Lycium Sp.*
MIBI	*Mimosa biuncifera* Benth.
NOTE	*Nolina texana* Wats.
QUGA	*Quercus gambelii* Nutt.
QUMU	*Quercus muehlenbergii* Engelm.
QUUN	*Quercus* Aff. *undulata*
QUUN	*Quercus undulata* Torr.
SYRO	*Symphoricarpos rotundifolius* Gray.
GUMI	*Xanthocephalium microcephalum* (DC)Shinners.
GUSA	*Xanthocephalum sarothrae* (Pursh)Shinners.
GUTIE	*Xanthocephalum* Sp.
YUBA	*Yucca baccata* Engelm.

III. Graminoids

AGTA	*Agropyron trachycaulum* (Link) Malte.
AGEX	*Agrostis exarata* Trin.
ANBA	*Andropogon barbinodis* Lag.
ANGE	*Andropogon gerardi* Vitman.
ANSC	*Andropogon scoparius* Michx.
ARAR	*Aristida arizonica* Vasey.
ARBA	*Aristida barbata* Fourn.
ARFE	*Aristida fendleriana* Steud.
ARGL	*Aristida glauca* (Nees) Walp.
ARWA	*Aristida wrightii* Nash.
BOBR	*Bouteloua breviseta* Vasey.
BOCU	*Bouteloua curtipendula* (Michx.) Torr.
BOER	*Bouteloua eriopoda* (Torr.) Torr.
BOGR	*Bouteloua gracilis* Lag. ex Steud.
BOHI	*Bouteloua hirsuta* Lag.
BRAN	*Bromus anomalus* (Shear) Hitchc.
BRFR	*Bromus frondosus* (Shear) Woot and Standl.
ERER	*Eragrostis erosa* Scribn.
ERIN	*Eragrostis intermedia* Hitchc.
HIJA	*Hilario jamesii* (Torr.) Benth.
KOCR	*Koeleria cristata* (L.) Pers.
LYPH	*Lycuris phleoides* H.B.K.
MUAR	*Muhlenbergia arenicola* Buckl.
MUDU	*Muhlenbergia dubia* Fourm.
MUEM	*Muhlenbergia emersleyi* Vasey.
MUME	*Muhlenbergia metcalfei.*
MUMO	*Muhlenbergia Montana* (Nutt.) Hitchc.
MUPA	*Muhlenbergia pauciflora* Buckl.
MURE	*Muhlenbergia setifolia* Vasey.
MUTO	*Muhlenbergia torreyi* (Kunth)Hitch.ex.Bush.
ORBL	*Oryzopsis bloomeri* (Boland.) Ricker.
OEMI	*Oryzopsis micrantha* (Trin. and Rupr.)Thurb.
PABU	*Panicum bulbosum* H.B.K.
PAOB	*Panicum obtusum* H.B.K.
PAHA	*Panicum hallii* Vasey.
PIFI	*Piptochaetium fimbriatum* (H.B.K.)Hitchc.
SEMA	*Setaria macrostachy* H.B.K.
SIHY	*Sitanion hystrix* (Nutt.) J.G.Smith.
SPCR	*Sporobolus Cryptandrus* (Torr.) Gray.
STCO	*Stipa columbiana* Macoun.
STLE	*Stipa lettermani.*
STNE	*Stipa neomexicana.*
STSC	*Stipa scribneri* Vasey.
STTE	*Stipa tenuissima* Trin.
TRMU	*Tridens muticus* (Torr.) Nash.
TRPIL	*Tridens pilosus* (Buckl) Hitchc.

IV. Forbs

ACNEO	*Acalypha neomexicana* Muell. Arg.
ACLA	*Achillea millefolium* (Nutt.) Piper.
ALCE	*Allium cernuum* Roth.
ALDR	*Allium drummondil* Regel.
ANCR	*Ampda cristata* (L.) Schlecht.
ANTO	*Antheicum torreyi* Baker.
ARTH	*Arabidopsis thaliana* (L.) Heynh.
ARABIS	*Arabis Sp.*
ARCO	*Arenaria confusa* Rydb.
ARGL	*Artemisia glauca* Pall.
ARLU	*Artemisia ludoviciana* Nutt.
ARFRI	*Artemisia frigida* Willd.
ASAS	*Asclepias asperula* (Dene) Woods.
ASPR	*Aster praealtus* Poir.
ASTER	*Aster sp.*
ASFL	*Astragalus flexuosus* Dougl.
ASPI	*Astragalus pictiformis* Barneby.
BADI	*Bahia dissecta* (Gray) Britt.
BELY	*Berlandiera Lyrata* Gray.
BRER	*Brickellia brachyphylla* Gray.
BRFE	*Brickellia Fendleri* Gray.
BRGR	*Brickellia grandiflora* (Hook.) Nutt.
BRRU	*Brickellia rusbyi* Gray.
CAHU	*Calliandra humilis* (Schlecht.)L.Benson
CAINT	*Castilleja integra* Gray.
CODT	*Commelina dianthifolia* Delile.
	Cruciferae sp.
CRJA	*Cryptantha jamesii* (Torr.) Payson
	Cyperus sp.
CYRU	*Cyperus rusbyi* Britton.
DAFR	*Dalea frutescens* Gray
DIBR	*Dichondra brachypoda* Woot. and Sandl.
ERMO	*Erigeron modestus* Gray.
ERFL	*Erigeron flagellaris* Gray.
ERAL	*Eriogonum alatum* Torr.
ERHI	*Eriogonum hieracifolium* Benth.
ERJA	*Eriogonum jamesii* Benth.
ERCA	*Erysimum capitatum* (dougl) Greene
EUWR	*Eupatorium wrightii* Gray.
EUDE	*Euphorbia dentata* Michx.
EUFE	*Euphorbia fendleri* Torr. & Gray.
EUSI	*Euphorbia simulans* (Wheeler)Warnock
EURE	*Euphorbia revoluta* Engelm.

GAMI	Galium microphyllum Gray.
GECA	Geranium caespitosum James.
GIAG	Gilia aggregata (Pursh) Spreng.
GIRI	Gilia rigidula var. acerosa (Gray) Wherry.
GUDE	Guilleminea densa (Willd.) Mog.
GYGL	Gymnosperma glutinosum (Spreng) Less.
HADI	Halimolobos diffusa (Gray.) Shulz.
HECO	Hedeoma costatum Gray.
HEDR	Hedeoma drummondii Benth.
HEOB	Hedeoma oblongifolium (Gray) Heller.
HEAC	Hedyotis acerosa Gray.
HENI	Hedyotis nigricans (Lam.) Fosb.
HIFE	Hieracium fendleria Schultz Bip.
HYAC	Hymenoxys acaulis (Pursh) Parker.
LEMO	Lepidium montanum Nutt.
LEVA	Lesquerella valida Greene.
LIAR	Linum aristatum Engelm.
LINE	Linum neomexicanum Greene.
LIMU	Lithospermum multiflorum Gray.
MAAS	Machaeranthera australis (Green) Shinners.
MABI	Machaeranthera biglovii (Gray) Greene.
MABL	Machaeranthera blephariphylla (Gray)Shinners.
MELU	Melampodium leucanthum Torr. & Gray.
MELO	Menodora longiflora Gray.
MESC	Menordora scabra Gray.
MIDI	Mirabilis diffusa (Heller) Reed.
MIMU	Mirabilis multiflora (Torr.) Gray.
MIOX	Mirabilis oxybaphoides (Gray) Gray.
MOLA	Monotropa latisquama (Rydb) Hult.
NOTHO	Notholaena sinuata (Lag.) Kaulf.
OENOTH	Oenothera sp.
OXME	Oxalis metcalfei (Small) Kunth.
OXSE	Oxytropis sericea Nutl.
PAJA	Paronychia jamesii Torr. & Gray.
PECTAN	Pectis angustifolia Torr.
PEBA	Penstemon barbatus (Ca.)Roth.
PENE	Penstemon neomexicana Gray.
PHTR	Phlox triovulata Torr.
PHLO	Physalis virginiana (Torr.) Waterfall.
POAL	Polygala alba Nutt.
POLO	Polygala longa Blake.
PTAQ	Pteridium aquilinum (L.) Kuhn.
RACO	Ratibida columnaris (Sims) D. Don.
SAAB	Sanvitalia abertii Gray.
SILI	Sisymbrium linearifolium (Gray) Pays.
SOFE	Solanum fendleri Gray.
SOWR	Solidago wrightii Gray.
SPHAER	Sphaeralcea coccinea (Pursh) Rydb.
THLO	Thelesperma longipes Gray.
SILI	Thelypodiopsis leariifolium
TRRA	Tragia ramosa Torr.
FRASE	Frasera sp.
VECI	Verbena ciliata Benth.
VENE	Verbena neomexicana (Gray) Small
VIDE	Viguiera dentata (Cav.) Spreng.
VIMU	Viguiera multiflora (Nutt.) Blake.
ZIGR	Zinnia grandiflora Nutt.

KEY TO PINYON-JUNIPER HABITAT TYPES OF THE LINCOLN NATIONAL FOREST

1. Juniperus deppeana present (regeneration evident, not accidental)..2

1. Juniperus deppeana absent or accidental......................3

2. Muhlenbergia dubia dominant in understory, or occurring with PIFI and MUEM............................. PIED-JUDE/MUDU HT

2. Bouteloua gracilis dominant in understory.... PIED-JUDE/BOGR HT

3. Pinus edulis clearly dominant in tree coverage, with Stipa columbiana dominant in understory........... PIED-JUMO/STCO HT

3. Pinus edulis codominant or secondary to Juniperus monosperma in tree coverage...4

4. Juniperus monosperma dominant in tree coverage, Muhlenbergia pauciflora dominant in understory............PIED-JUMO/MUPA HT

4. Pinus edulis and Juniperus monosperma codominant in tree coverage 5

5. Poorly developed understory, grasses ANGE,BOGR, and BOCU present at low levels, the shrub CEMO frequently present...............................PIED-JUMO/CEMO/ANGE HT

5. Well developed understory, the grass Bouteloua gracilis dominant.................................PIED-JUMO/BOGR HT

Preliminary Habitat Types of a Semiarid Grassland[1]

Richard E. Francis and Earl F. Aldon[2]

Abstract.--Twenty-five habitat types including two phases were described and quantified for a semiarid grassland in northwestern New Mexico; the vegetation variables of cover, density, and frequency were used to form hierarchical importance values. Associated with the habitat types are five landforms and forty-two soil series or associations. This study allows for extrapolation of information to similar areas and acts as an ecological base for management prescriptions.

Keywords: Habitat types, semiarid grassland, importance values

INTRODUCTION

The need for habitat type descriptions in the Southwest has long been evident, especially on the Rio Puerco Resource Area located in northwestern New Mexico (Aldon 1964). Past research findings on the area have been limited in their extrapolation because of the lack of reliable widespread habitat data (Aldon and Garcia 1971). A significant research finding was usually limited to the site where the study was conducted; results extended beyond the study areas could be misleading. Principles learned from such research were sound. However, habitats were not measured or comparable, and therefore, extension of findings was limited and the need for compatibility is evident (Francis 1978). To satify this need, a study to quantify habitat types on a semiarid grassland area of over 15,600 km^2 in size was begun.

An agreed upon set of variables which include vegetation, soils, and landform (Merkel et al. 1982) was used. The vegetation component was an extension of the Brown, Lowe, and Pase classification for the Southwest (Brown et al. 1979). The soils component was from the Cabezon Peak soils survey conducted by Bureau of Land Management and Soil Conservation Service personnel (Folks and Stone 1968). An outline of the methods used and preliminary results follows.

A. Five classes of landforms were used to designate erosion class and livestock use patterns.

1. Mesas and ridge tops
2. Colluvial slopes (10% slopes or greater)
3. Lower alluvial slopes (2% to 10% slopes)
4. Alluvial flats (0% to 2% slopes)
5. Breaks or rough country with steep topography.

B. Forty-two soil series were identified on the study area based on the Cabezon Peak soil survey.

C. The Community Structure Analysis (CSA) method (Pase 1981) was used to sample 294 transects in 112 sites (e.g., Fig. 1).

D. Cover, density, and frequency data from the CSA method were used in program COSAM to calculate the species importance values.

E. The importance values were ordered using program HIERARCH. This resulted in 25 preliminary vegetation associations including two phases; typal associations are keyed to ground locations.

F. The vegetation associations were combined with soils to form 25 preliminary habitat types (h.t.).

(1) PINUS PONDEROSA/CAREX SPP. - POA FENDLERIANA h.t.

Species	Importance Value
Pipo	0.651
CARE spp.	0.455
Pofe	0.286

Soil Series: Cabezon, Travaesilla/Shingle

[1]Paper presented at the Workshop on Southwestern Habitat Types, Albuquerque, New Mex., April 6-8, 1983.

[2]Range Scientist and Research Forester, Rocky Mountain Forest and Range Experiment Station, Albuquerque, New Mexico 87106. Headquarters is in Fort Collins, in cooperation with Colorado State University.

RIO PUERCO

ALLOTMENT 2 SHROYER
PASTURE EAST TRANSECT NO. 092
VEGETATION TYPE 1 PLANT COVER 27.675 LITTER 10.725 ROCK 0.000 BARE 61.600

SPECIES IDENTIFICATION

SPECIES	SCIENTFIC NAME	COVER	DENSITY	FREQUENCY	IMPORTANCE VALUE
AGDE	AGROPYRON DESERTORUM	8.975	9.30	.90	.665
AGSM	AGROPYRON SMITHII	2.025	18.60	.40	.496
BOGR	BOUTELOUA GRACILIS	4.200	8.80	.60	.428
ASTR	ASTRAGALUS SP.	3.525	5.00	.80	.369
ARTR	ARTEMISIA TRIDENTATA	4.525	.90	.40	.254
GUSA	GUITERREZIA SAROTHRAE	.650	3.00	.70	.209
ERLO1	ERIOGONUM LONCHOPHYLLUM	1.425	1.90	.20	.124
HIJA	HILARIA JAMESII	.875	2.00	.20	.106
TAPA1	TALINUM PARVIFLORUM	.100	.60	.30	.070
LALE	LATHYRUS LEUCANTHUS	.200	.90	.20	.061
MEOF	MELILOTUS OFFICINALIS	.300	.90	.10	.046
SPDI	SPHAERALCEA DIGITATA	.050	.30	.20	.044
POPA	POA PALUSTRIS	.050	.60	.10	.032
GRAR	GRINDELIA ARIZONICA	.225	.10	.10	.029
SPCR	SPOROBOLUS CRYPTANDRUS	0.000	.20	.10	.022
ERMI	ERIOGONUM MICROTHECUM	0.000	.20	.10	.022
OPPO	OPUNTIA POLYACANTHA	.225	0.00	0.00	.008
ARNO	ARTEMISIA NOVA	.200	0.00	0.00	.007
SIHY	SITANION HYSTRIX	.100	0.00	0.00	.004
STCO1	STIPA COMATA	.025	0.00	0.00	.001
	TOTALS	27.675	53.30		2.997
	DIVERSITY		1.99		

---NOTE---
SUMMARY IS FOR EACH TRANSECT IN THE PASTURE

Figure 1.--Example of printout from program COSAM showing data obtained from the Community Structure Analysis method and importance values used in program HIERACH.

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(2) JUNIPERUS MONOSPERMA / BOUTELOUA GRACILIS h.t.

Species	Importance Value
Jumo	0.638
Bogr	0.512

Soil Series: Sheppard variant

(3) PINUS EDULIS / BOUTELOUA GRACILIS - ERIOGONUM SPP. h.t.

Species	Importance Value
Pied	0.233
Bogr	0.314
ERIO spp.	1.472

Soil Series: Sandstone

(4) PINUS EDULIS - JUNIPERUS MONOSPERMA / BOUTELOUA GRACILIS h.t.

Species	Importance Value
Pied	0.019
Jumo	0.012
Bogr	0.599

Soil Series: Billings, Persayo, Travesilla

(5) SARCOBATUS VERMICULATUS / AGROPYRON SMITHII - SITANION HYSTRIX h.t.

Species	Importance Value
Save	1.681
Agsm	0 .272
Sihy	0.325

Soil Series: Christianberg, Navajo

(6) ATRIPLEX CUNEATA - FRANKENIA JAMESII / SPOROBOLUS AIROIDES h.t.

Species	Importance Value
Atcu	0.510
Spai	1.033
Frja	0.416

Soil Series: Shingle complex

(7) ATRIPLEX CANESCENS / SPOROBOLUS AIROIDES - SITANION HYSTRIX h.t.

Species	Importance Value
Atca	0.927
Spai	0.891
Sihy	0.312

Soil Series: Billings variant, Alkali alluvial, Christianberg

(8) ATRIPLEX CANESCENS / HILARIA JAMESII - SPOROBOLUS CONTRACTUS h.t.

Species	Importance Value
Atca	0.707
Hija	0.669
Spco	0.378

Soil Series: Litle, Las Lucas

(9) ATRIPLEX CANESCENS / BOUTELOUA GRACILIS - SPOROBOLUS SPP. h.t.

Species	Importance Value
Atca	0.256
Bogr	0.480
SPOR spp.	1.019

Soil Series: Sheppard variant

(10) CHRYSOTHAMNUS NAUSEOSUS / BOUTELOUA GRACILIS h.t.

Species	Importance Value
Chna	0.174
Bogr	2.100

Soil Series: Penistaja, Berent

(11) CHRYSOTHAMNUS PARRYI / BOUTELOUA GRACILIS - HILARIA JAMESSI h.t.

Species	Importance Value
Chpa	0.289
Bogr	0.464
Hija	0.638

Soil Series: Penistaja, Christianberg, Navajo

(12) ARTEMISIA NOVA - ARTIMISIA TRIDENTATA / AGROPYRON SMITHII h.t.

Species	Importance Value
Arno	0.701
Artr	0.331
Agsm	0.372

Soil Series: Galiseto association

(13) ARTEMISIA TRIDENTATA / BOUTELOUA GRACILIS - AGROPYRON SMITHII h.t.

Species	Importance Value
Artr	0.512
Bogr	0.781
Agsm	0.532

Soil Series: Billings, Persayo

(14) ARTEMSIA TRIDENTATA / HILARIA JAMESII - BOUTELOUA GRACILIS h.t.

Species	Importance Value
Artr	0.583
Hija	0.782
Bogr	0.325

Soil Series: Poleo, Galiseto, Atrac, Las Lucas, Christianberg, Fruitland, Penistaja, Kim, Billings variant

(15) ARTEMISIA TRIDENTATA / HILARIA JAMESII - SPOROBOLUS CRYPTANDRUS h.t.

Species	Importance Value
Artr	0.390
Hija	0.869
Spcr	0.741

Soil Series: Penistaja

(16) ARTEMISIA TRIDENTATA / SPOROBOLUS CRYPTANDRUS - ORYZOPSIS HYMENOIDES h.t.

Species	Importance Value
Artr	0.416
Spcr	1.367
Orhy	0.110

Soil Series: Billings, Persayo

(17) AGROPYRON SMITHII - BOUTELOUA GRACILIS - SPOROBOLUS AIROIDES h.t.

Species	Importance Value
Agsm	0.781
Bogr	0.664
Spai	0.656

Soil Series: Christianberg

(18) SPOROBOLUS NEALLEYI - BOUTELOUA ERIOPODA h.t.

Species	Importance Value
Spne	0.777
Boer	0.754

Soil Series: Gypsum land, rock outcrop

(19) BOUTELOUA ERIOPODA h.t.

Species	Importance Value
Boer	0.823

Soil Series: Kim loam, basalt outcrop

(20) HILARIA JAMESII h.t.

Species	Importance Value
Hija	1.443

Soil Series: Las Lucas, Billings variant, Gypsum

(21) HILARIA JAMESII - SPOROBOLUS AIROIDES h.t. Phase

Species	Importance Value
Hija	1.512
Spai	0.708

Soil Series: Shingle complex, Sheppard variant, Kim loam, Las Lucas, Litle

(22) HILARIA JAMESII - BOUTELOUA GRACILIS h.t. Phase

Species	Importance Value
Hija	1.061
Bogr	0.472

Soil Series: Shingle complex, Alkali, Persayo

(23) SPOROBOLUS AIROIDES h.t.

Species	Importance Value
Spai	1.766

Soil Series: Alkali alluvial, Christianberg, Fruitland, Las Lucas

(24) SPOROBOLUS AIROIDES - BOUTELOUA GRACILIS - HILARIA JAMESII h.t.

Species	Importance Value
Spai	1.062
Bogr	0.897
Hija	0.352

Soil Series: Litle, Las Lucas

 

The Save/Agsm-Sihy h.t. consists of scattered to dense salt-tolerant shrubs with little understory of perennial herbs or grasses. The aspect is a uniform to dense stand of greasewood interspersed with western wheatgrass and bottlebrush squirreltail. This association type is found on dry alluvial plains at elevations that vary from 1,300 to 2,600 m. The potential natural vegetation of western wheatgrass and bottlebrush squirreltail represents desirable forage. As the range deteriorates, greasewood increases in dominance.

The soils in this association are characterized by alluvium terraces of the Christianburg and Navajo series. These soils vary from poorly drained to well drained clays and clay loams. The soils are generally saline and suited to salt-tolerant grasses.

Figure 2.--Example of photographs and narrative description for (5) SARCOBATUS VERMICULATUS/AGROPYRON SMITHII-SITANION HYSTRIX h.t. (Save/Agsm-Sihy h.t.)

(25) BOUTELOUA GRACILIS - HILARIA JAMESII h.t.

Species	Importance Value
Bogr	1.330
Hija	0.755

Soil Series: Shingle complex, basalt, Cabezon, Traversilla, Las Lucas, Persayo

G. A dichotomous site key was developed using vegetation, soils, and landform; inferences to potential natural vegetation were included.

H. Each preliminary h.t. was described by a narrative and site photographs. (e.g.--Fig. 2).

Application

1. Compatible base for nomenclature, variables, and identification.

2. Common prescription base for management, treatment, and assessment of ecological stage.

3. Base for further hierarchical aggregation in both the current and climax context; ties with accepted National schemes.

4. Stratification base for inventory and monitoring.

Needs

1. Terminology agreement; habitat type, range site, association type, ecological site type, community type, etc.

2. Development of criteria for appropriate variables, variance standards, sample design, measurement techniques.

3. Determination of ecological stage, potential vegetation, and production.

4. Information transfer and application, including an AT map.

5. Refinement of soil-vegetation correlation.

6. Development of management prescriptions.

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Sagebrush-Steppe Habitat Types in Northern Colorado: A First Approximation [1]

SUMMARY

Richard E. Francis[2]

Abstract.--Seventeen habitat types in a northern Colorado park basin have been quantified and classified in relation to plant species dominance, canopy cover, frequency, species richness, constancy, and topoedaphic characteristics. These habitat types are considered first approximations and are classified as zootic, climatic, edaphic, and/or topographic. The ecological information presented forms an ecological data base useful for management planning and monitoring successional stages of the plant communities described.

Keywords: Habitat types; classification; Middle Park, Colorado; sagebrush

INTRODUCTION

Habitat types (Daubenmire 1968) form a basis for applying management prescriptions to areas of similar environs, and are an integral part of resource inventory because they establish uniform classification standards for sampling.

The habitat types described here are not pristine climax units, but are considered first approximations of stable phytoedaphic communities. Also, they are not Southwestern habitat types per se, but their concept, sampling, and classification are applicable to this workshop.

The 17 habitat types described are considered zootic, climatic, edaphic, and/or topoedaphic.[3] Zootic habitat types are considered stable when continually influenced by livestock grazing (Daubenmire 1970) and concentrated browsing by mule deer which use the area as critical winter range during deep snow winters. All of the climax categories listed above are not exclusive of one another; one may have an influence on, or may be a derivative of another.

This study was designed to provide a portion of an ecological data base to aid in the development of techniques to classify, inventory, and manage our natural resources. Also, this study provided a basis for further research and assessment of mule deer (<u>Odocoileus hemionus</u>) winter range carrying capacity (Strong 1980).

The results from this study are summarized in outline form below.

<u>Study Area</u>

1. Middle Park, north-central Colorado. Vegetation aspect dominated by big sagebrush (<u>Artemisia tridentata</u>) at elevations of 2,230 - 2,650 m.

2. The average precipitation over the past 41 years was 39.93 cm (15.72 in) per year (National Oceanic and Atmospheric Administration 1977).

<u>Sampling</u>

1. The area was stratified using geologic and soils maps.

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[1]Presented at the Workshop on Southwestern Habitat Types, Albuquerque, N. Mex., April 6-8, 1983.

[2]Range Scientist,Rocky Mountain Forest and Range Experiment Station, Albuquerque, New Mexico 87106. Headquarters is in Fort Collins, in cooperation with Colorado State University.

[3]Tiedeman, J. A., R. E. Francis, C. Terwilliger, Jr., and L. H. Carpenter. In preparation. Steppe habitat types of Middle Park, Colorado: A first approximation. USDA Forest Service General Technical Report, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colo.

2. Variable sized study sites were selected from this stratification based upon apparent homogeneity of landform, soils, slope, aspect, and vegetation.

3. Vegetation was sampled using two approaches: (a) reconnaissance--layer-dominance ratings used to form nine apparent habitat types in the critical mule deer winter range, and (b) detailed--canopy cover (Daubenmire 1970) from a minimum of thirty - 20 x 50 cm quadrats.

4. Quadrats were at 3-pace intervals along two parallel transects within each sample site; transects were 15 paces apart.

5. Canopy cover was recorded in 15 percentage classes: 0%, 1%, 2%, 3%, 4%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100%.

6. Species richness was recorded as the number of species within each stand.

7. Phenology for major species was recorded every two weeks.

8. Soil series (or associations) were taken from previously published surveys.

9. All species were identified according to Harrington (1964) except the species and subspecies of Artemisia, which were according to Beetle (1960) Beetle and Young (1965), and Stevens and McArthur (1974). All subspecies were verified by McArthur.[4]

10. Grazing and browsing was rated as slight, moderate, or heavy.

11. Successional stage was subjectively categorized as climax, stable, late seral, or early seral.

12. Climax categories were edaphic, climatic, zootic, and topographic.

Results

1. Use of subjectively ranked mean canopy cover, constancy,[5] species richness, species frequency, and soil series resulted in 17 habitat types (h.t.); nine intensively measured h.t. in the mule deer critical winter range, eight in the adjacent steppe area.

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[4]Personal communication from E. D. McArthur. 1979. USDA Forest Service, Shrub Sciences Laboratory, Provo, Utah.

[5]Constancy refers to the number of sample sites within a habitat type in which a particular species was found. The number of sites sampled per habitat type is shown in parentheses.

A. Habitat types within the mule deer critical range

(1) ARTEMISIA TRIDENTATA TRIDENTATA/AGROPYRON SMITHII h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean	percent) - -	
Artrt	34	92	6
Agsm	4	48	6

Successional Stage: Late seral-stable
Species Richness: 33
Soil Series: Harsha (fine-loamy, mixed Borollic Haplargid)
Land Form: Upland swale, dry alluvial stream terrace
Climax Category: Topo-edaphic

(2) SARCOBATUS VERMICULATUS-ARTEMISIA TRIDENTATA TRIDENTATA/AGROPYRON SMITHII h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean	percent) - -	
Save	10	36	6
Artrt	21	67	6
Agsm	3	29	6

Successional Stage: Stable
Species Richness: 30
Soil Series: Harsha (fine-loamy, mixed Borollic Haplargid)
Binco clay loam
Leavitte loam
Land Form: Alluvial fans, toe slopes
Climax Category: Topo-edaphic

(3) ARTEMISIA TRIDENTATA WYOMINGENSIS/AGROPYRON SMITHII h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean	percent) - -	
Artrw	25	83	6
Agsm	9	81	6

Successional Stage: Stable-late seral
Species Richness: 31
Soil Series: Harsha (fine-loamy, mixed Borollic Haplargid) Leavitte
Land Form: Undulating terrace, plateau tops
Climax Category: Climatic

(4) ARTEMISIA TRIDENTATA WYOMINGENSIS/AGROPYRON SPICATUM h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean	percent) - -	
Artrw	25	83	6
Agsp	8	61	6

Successional Stage: Stable
Species Richness: 40
Soil Series: Quander (loamy-skeletal, mixed Argic Cryoboroll)
Bearmouth
Leavitte
Yovimpa
Land Form: Sloping uplands, ridges, gravelly outwash terrace
Climax Category: Edaphic (gravelly)

(5) AGROPYRON SPICATUM/ARTEMISIA FRIGIDA h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean percent) - -		
Agsp	14	85	6
Arfr	2	34	6

Successional Stage: Stable
Species Richness: 62
Soil Series: Rogert (loamy-skeletal, mixed Lithic Cryoboroll)
Quander
Bearmouth
Land Form: Windswept gravelly ridgetops
Climax Category: Topographic

(6) JUNIPERUS SCOPULORUM/AGROPYRON SPICATUM h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean percent) - -		
Jusc	23	49	6
Agsp	8	46	6

Successional Stage: Stable--late seral
Species Richness: 46
Soil Series: -- (Cryoboroll)
Land Form: Steep, rocky, stoney ridges; mountain slopes
Climax Category: Edaphic

(7) ARTEMISIA TRIDENTATA VASEYANA/FESTUCA IDAHOENSIS h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean percent) - -		
Artrv	25	87	6
Feid	3	31	4

Successional Stage: Stable--late seral
Species Richness: 55
Soil Series: Leavitte (fine-loamy, mixed Argic Cryoboroll) Quander
Land Form: Swales, shallow snowdrift depressions
Climax Category: Climatic

(8) AMELANCHIER ALNIFOLIA/AGROPYRON SPICATUM h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean percent) - -		
Amal	16	37	6
Agsp	18	77	6

Successional Stage: Stable
Species Richness: 46
Soil Series: Rogert (loamy-skeletal, mixed Lithic Cryoboroll)
Land Form: Steep cobbly-gravelly mountain slopes
Climax Category: Edaphic

(9) AMELANCHIER ALNIFOLIA/CAREX h.t.

Species	Cover	Frequency	Constancy (6)
	- - (mean percent) - -		
Amal	44	81	6
Carex sp.	40	81	6

Successional Stage: Stable
Species Richness: 61
Soil Series: Clayburn (fine-loamy, mixed Argic Pacic Cryoboroll)
Handren
Land Form: Snowdrift accumulation sites
Climax Category: Topographic

(10) CHRYSOTHAMNUS PARRYI-ORYZOPSIS HYMENOIDES/ERIOGONUM BREVICAULE h.t.

Species	Dominance rating	Constancy (8)
	- - (mean) - -	
Chpa	4.5	8
Orhy	3.5	8
Erbr	3	5

Successional Stage: ---
Species Richness: 54
Soil Series: Yovimpa (clayey, mixed, shallow, typic Cryorthent) Binco, Roxal, Harsha
Land Form: Badlands, eroded slopes
Climax Category: Topo-edaphic

(11) ORYZOPSIS HYMENOIDES/ERIOGONUM BREVICAULE h.t.

Species	Dominance rating	Constancy (6)
	- - (mean) - -	
Orhy	4	5
Erbr	3	6

Successional Stage: ---
Species Richness: 40
Soil Series: ---
Land Form: Badlands, rolling, ridgetops
Climax Category: Topographic

B. Habitat types within the adjacent steppe region

(12) ARTEMISIA LONGILOBA/POA SECUNDA h.t.

Species	Dominance rating	Constancy (4)
	- - (mean - -	
Arlo	5	4
Pose	3	4

Successional Stage: ---
Species Richness: 24
Soil Series: ---(Argic Cryoboroll)
Land Form: Rolling uplands, alluvial fans
Climax Category: Edaphic

(13) ARTEMISIA TRIDENTATA WYOMINGENSIS/STIPA COLUMBIANA h.t.

Species	Dominance rating	Constancy (5)
	- - (mean) - -	
Artrw	5	5
Stco	3	4

Successional Stage: --
Species Richness: 34
Soil Series: Harsha (fine-loamy, mixed Borollic Haplargid)
Land Form: Plateau tops
Climax Category: Climatic

(14) PURSHIA TRIDENTATA-ARTEMISIA TRIDENTATA VASEYANA/FESTUCA IDAHOENSIS h.t.

Species	Dominance rating - - (mean) - -	Constancy (9)
Putr	3.5	9
Artr	5	5
Feid	3.5	4

Successional Stage: --
Species Richness: 67
Soil Series: ---
Land Forms: Rolling uplands, mountain slopes
Climax Category: Edaphic

(15) AGROPYRON SPICATUM/POA FENDLERIANA h.t.

Species	Dominance rating - - (mean) - -	Constancy (3)
Agsp	4	2
Pofe	3	3

Successional Stage: --
Species Richness: 41
Soil Series: Quander (loamy-skeletal, mixed Lithic Cryoboroll)
Land Form: Windswept ridgetops
Climax Category: Topo-edaphic

(16) ARTEMISIA TRIDENTATA VASEYANA/FESTUCA THURBERI h.t.

Species	Dominance rating - - (mean) - -	Constancy (6)
Artrv	5	6
Feth	4	3

Successional Stage: --
Species Richness: 63
Soil Series: ---(Cryoboroll)
Land Form: Mountain slopes
Climax Category: Climatic

(17) ARTEMISIA CANA/FESTUCA THURBERI h.t.

Species	Dominance rating - - (mean) - -	Constancy (3)
Arca	5	3
Feth	4.5	3

Successional Stage: --
Species Richness: 42
Soil Series: Mord and Cimarron (fine montmorillonitic Boralfic Cryoboroll)
Land Form: Alluvial flood plains
Climax Category: Topographic

2. More than one soil series occurred within certain habitat types, and some series occurred in more than one habitat type; one series has been identified as modal.

3. Grazing by livestock and concentrated wildlife browsing (zootic climax) is, and has been, an important, continuous factor in the development and mainteinance of stable Middle Park plant communities.

4. A Soils Key to the sagebrush-steppe habitat types was developed.

5. Each h.t. was described by a narrative of important species, physical factors, relationship to other h.t.s, and a site photograph. (e.g.--fig. 1).

Application

1. Stratification base for inventory and monitoring.

2. Common prescription base for management, treatment, and assessment of ecological stage.

3. Compatible base for nomenclature, variables, and identification.

4. Base for further hierarchical aggregation in both the current and climax context; ties with accepted National schemes.

Needs

1. Refinement of soil-vegetation correlation.

2. Determination of ecological stage.

3. Development of management prescriptions.

4. Information transfer and application.

5. Terminology agreement; habitat types, range site, association type, ecological site type, etc.

6. Development of criteria for appropriate variables, variance standards, sample design, measurement techniques.

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This is an edaphic climax specific to gravelly soils. The overstory is dominated by Artemisia tridentata wyomingensis, which averages 35.6 cm in height. The understory is dominated by Agropyron spicatum. Other important members of the plant community include Chrysothamnus viscidiflorus var. viscidiflorus, Poa fendleriana, and Erigeron engelmannii.

Physical characteristics.

This habitat type occurs at elevations that range from 2,288 to 2,501 m, primarily on south- to west-facing slopes ranging from 0% to 65%. This habitat type is usually located on sloping uplands, ridges, and gravelly outwash terraces.

Most soils are gravelly as represented by the model Quander series, a member of the loamy skeletal, mixed family of Argic Cryoborolls. Other soils include the Bearmouth series, which is sandier, and the Leavitte and Yovimpa series, which contain less gravel. The parent material is usually gravelly outwash terrace or residual gneiss, granite, or sandstone. Geologic formations include Pierre Shale with a sandstone cap and Boulder Creek granodiorite.

Relation to other habitat types.

The Artemisia tridentata vaseyana/Festuca idahoensis habitat type occurs at higher elevations and in swale positons where soil temperatures are colder and snow accumulation is greater, resulting in a more mesic sites. The moisture-indicating species such as Lupinus species and Vicia americana do not usually occur in the Artemisia tridentata wyomingensis/Agropyron spicatum habitat type.

Figure 1.--Example of photograph and narrative description for (4) ARTEMISIA TRIDENTATA WYOMINGENSIS/AGROPYRON SPICATUM h.t.

Classification of Mixed Broadleaf Riparian Forest in Tonto National Forest [1]

Andrew W. Laurenzi, Robert D. Ohmart, and Valerie C. Hink [2]

Abstract.--Mixed broadleaf riparian forest stands in the Tonto National Forest were sampled along an elevational gradient. The data were analyzed by a variety of numerical classification techniques. Reciprocal averaging ordination and cluster analysis based on the Relative Importance Value (RIV) of each species in each stand revealed five forest types whose distribution is strongly related to elevation: Fremont cottonwood-willow, sycamore, alder, maple, and narrow-leaf cottonwood. In addition to elevation, the distribution of forest types is related to individual species' responses to physical factors that vary along the stream gradient, as determined by the physiological and life-history attributes of those species.

INTRODUCTION

In the Tonto National Forest the deciduous broadleaf forest formation is generally confined to streamside environments. Forest types within this formation are referred to as belonging to an interior deciduous riparian forest (Brown et al. 1977) and are widely recognized for their ecological importance (Carothers et al. 1974, Johnson and Jones 1977). Brown et al. (1977) have divided the interior deciduous riparian forest formation into two major vegetation types: cottonwood (Populus fremontii)-willow (Salix gooddingii) and mixed broadleaf. Our study is primarily concerned with the mixed broadleaf riparian forest type.

Mixed broadleaf forests are found along the lower-order (i.e., 1-3) mountain streams at elevations from 770-2300 m. These lower-order streams are tributaries of the major drainages in the Tonto National Forest (Verde, Salt, lower Tonto, and lower Cherry creeks). Typically they include a rich (for the Southwest) assemblage of deciduous broadleaf trees, with upwards of seven or eight species co-occurring within a stand (Brown 1982). The common Southwest riparian tree species belong to several widely distributed temperate genera. These species are Arizona sycamore (Platanus wrightii), alder (Alnus oblongifolia, A. incana ssp. tenuifolia), cottonwood (Populus fremontii, P. angustifolia), willow (Salix gooddingii, S. bonplandiana), velvet ash (Fraxinus pennsylvanica ssp. velutina), Arizona walnut (Juglans major), maple (Acer negundo, A. grandidentatum, A. glabrum), and net leaf hackberry (Celtis reticulata). Intermingled with these broadleaf trees may be a number of common Southwest upland trees: junipers (Juniperus spp.), oak (Quercus spp.), pine (Pinus spp.), true firs (Abies spp.), and Douglas fir (Pseudotsuga menziesii var. glauca).

Despite their ecological importance, mixed broadleaf forests have been little studied. The available information is primarily of a qualitative nature (Lowe 1964, Zimmerman 1969, Brown et al. 1977, Brown 1982). Only a few quantitative studies exist, and they are of limited geographical areas (Campbell and Dick-Peddie 1964, Freeman and Dick-Peddie 1970, Irvine and West 1979, Reichenbacher 1983). The present study is an elevational gradient analysis of mixed broadleaf forests over a large geographical area in central Arizona. The intentions of the study were two-fold: (1) to elucidate vegetation-environment relationships, and (2) to provide an initial classification of the mixed broadleaf forest in the Tonto National Forest.

[1] Paper presented at Workshop on Habitat Type Ecosystems of the Southwest. [Albuquerque, New Mexico, April 6-8, 1983].

[2] Respectively, Andrew W. Laurenzi, Field Biologist; Robert D. Ohmart, Associate Director; Valerie C. Hink, Field Biologist, The Center for Environmental Studies, Arizona State University, Tempe, Arizona.

STUDY AREA AND METHODS

All stands were within the Tonto National Forest in central Arizona. The northern boundary of the study area is marked by the Mogollon Rim, the southern terminus of the Colorado Plateau. The approximate southern boundary of the study area is the Salt River. Only four forest stands were located south of the Salt River, and three of these were located on streams which drained into it. Between these boundaries are a series of south-draining streams separated by large mountain ranges. From west to east these include the New River Mountains, Verde River, Mazatzal Mountains, Tonto Creek, Sierra Ancha Mountains, and Cherry Creek. The entire area is located within the Salt River watershed, an eastward extension of the lower Colorado River drainage net. Forest stands were on tributaries of the aforementioned higher-order streams. Elevations range from 750 m along the lower Salt and Verde rivers to 1540-1850 m along the south and west boundaries to upwards of 2460 m at the top of the Mazatzal Mountains, Sierra Ancha Mountains, and Mogollon Rim.

Forest stands were sampled to reflect as many points as was feasible along an elevational gradient. Stands ranged in elevation from 760 to 2175 m, and all were considered representative of the mixed broadleaf type. Stand selection was based on the following criteria: (1) presence of forest canopy of greater than 60% cover along 900 linear stream meters and dominated in part by deciduous broadleaf trees; (2) apparent homogeneity in tree species composition; (3) presence of a deciduous broadleaf tree $\geq$5 cm dbh (diameter breast height) in 75% of the sample plots; and (4) overall density of trees >5 cm is >200 trees/ha. Originally 50 stands on 44 streams were sampled, but four stands were eliminated based upon criteria (3) and (4).

Stands were sampled between February and September 1980. Thirty 15X15-m plots at 30-m intervals along a 900-m transect located parallel to the stream were used to sample each stand. The edge of the stream channel served as one of the plot boundaries. Characteristically, the stream channel edge was identified by the presence of woody vegetation, which signified the base flow water line (Sigafoos 1964). In certain instances at narrow, rocky canyon locations it was necessary to place sample plots at irregular intervals along the transect in order to insure inclusion within the forest. This was done infrequently, since forest stands were delineated to minimize the likelihood of this occurrence.

Within each plot the number of trees $\geq$5 cm dbh was recorded. All deciduous broadleaf trees encountered were placed in the following dbh classes using visual estimates: 5-10 cm, 11-20 cm, 21-40 cm, and >40 cm. Synthetic importance values for each deciduous broadleaf tree species within a stand were calculated in a manner analogous to Curtis and McIntosh (1951). Because dbh data were gathered in size classes, a basal area measure was computed in the following manner: octaval rank values were assigned to individuals in each size class (1, 2, 4, and 8, respectively). For each tree species within a stand, a rank value sum was calculated and divided by the total rank value sum of all tree species in that stand. This was considered to be the species' relative rank value. The relative importance value (RIV) for each species within a stand was the sum value of relative density plus relative rank value plus relative frequency value.

A total of 25 tree species was recorded in the vegetation survey, 17 of which were deciduous broadleaf trees. Six of these 17 were eliminated to reduce the number of zero entries in the data matrix and to restrict the gradient analysis to trees that generally occur only in riparian environments as determined from previous forest studies in Arizona (Whittaker and Niering 1965, Moir and Ludwig 1979). The RIV values of the remaining 11 species were arrayed in a standard species-by-sample matrix, and the resulting matrix was subjected to numerical techniques.

Stands were located on USGS topographical maps. Upstream and downstream sampling end point elevations were estimated to the nearest 3 m from map contours. Stand elevation was the mid-point of the sample's elevational end points. Stream gradient was computed as the elevational drop in meters along a 1500-m length of stream centered over the stand. Gradient is expressed as the fall in meters per meter of stream. Composite elevational transects were created by examining the sequence of stand elevations for breaks (Laurenzi 1982).

Nomenclature was after Lehr (1978). Reliable field identification of *Salix gooddingii* and *S. bonplandiana* could not be made in the earlier months of the study, and willows were therefore recorded as *Salix* spp. for all forest stands. This was also true for *Juniperus monosperma* and *J. osteosperma*.

Reciprocal averaging (RA) ordination available through the Cornell Ecology Program Series (Gauch 1977) was run on the data matrix. Ordination seeks to arrange samples, plots, stands, etc. along a number of community-level axes of variation. These community-level axes are then related to one or more environmental gradients that provide an ecological context from which community structure can be conceptualized (Gauch 1977). Spearman rank correlation coefficients (Siegel 1956) were used to test for significant relationships between stand rank order and stand elevation.

Classification of forest stands was accomplished using a hierarchical, agglomerative clustering technique available through the CLUSTAN computer package (Wishart 1978). Originally classification was viewed as antagonistic to the aims of ordination, but it is

now accepted that when used together these approaches to the study of plant communities can complement one another and provide additional insight beyond that provided by one technique alone (Grigal and Goldstein 1971, Robertson 1978). Cluster analysis was employed as follows: the RIV for each species within a stand was standardized and standard distance between stands was calculated using squared Euclidean distance (Orloci 1978). Stands were clustered with the Ward's method variable combinatorial transformation (Orloci 1967).

RESULTS

The RA first-axis ordination produced an optimal sequence of samples and species in relation to each other by arranging the primary data matrix to concentrate higher values along the matrix diagonal (Gauch et al. 1977). This revealed an even continuum of species replacements among sequenced stands extending from Fremont cottonwood and willows through box elder (*Acer negundo*) and big tooth maple (*A. grandidentatum*).

This gradient in species composition among stands corresponded strongly to elevation (fig. 1). RA first-axis stand rank order was highly significantly correlated with stand elevation ($r_s = 0.912$, $P<0.0001$). Two-dimensional ordination of stands revealed a substantial second axis of variation. In RA, first and second axes accounted for 31 and 16% of the variation among stands, and no significant positive association was found between them.

The two-dimensional RA ordination of species illustrated three definable groupings (fig. 2). Groups identified were Fremont cottonwood-willow, Arizona sycamore-velvet ash-net leaf hackberry, and Arizona alder (*Alnus oblongifolia*)-Arizona walnut. Narrow-leaf cottonwood (*Populus angustifolia*), box elder, and big tooth maple did not appear to cluster with each other or any other species.

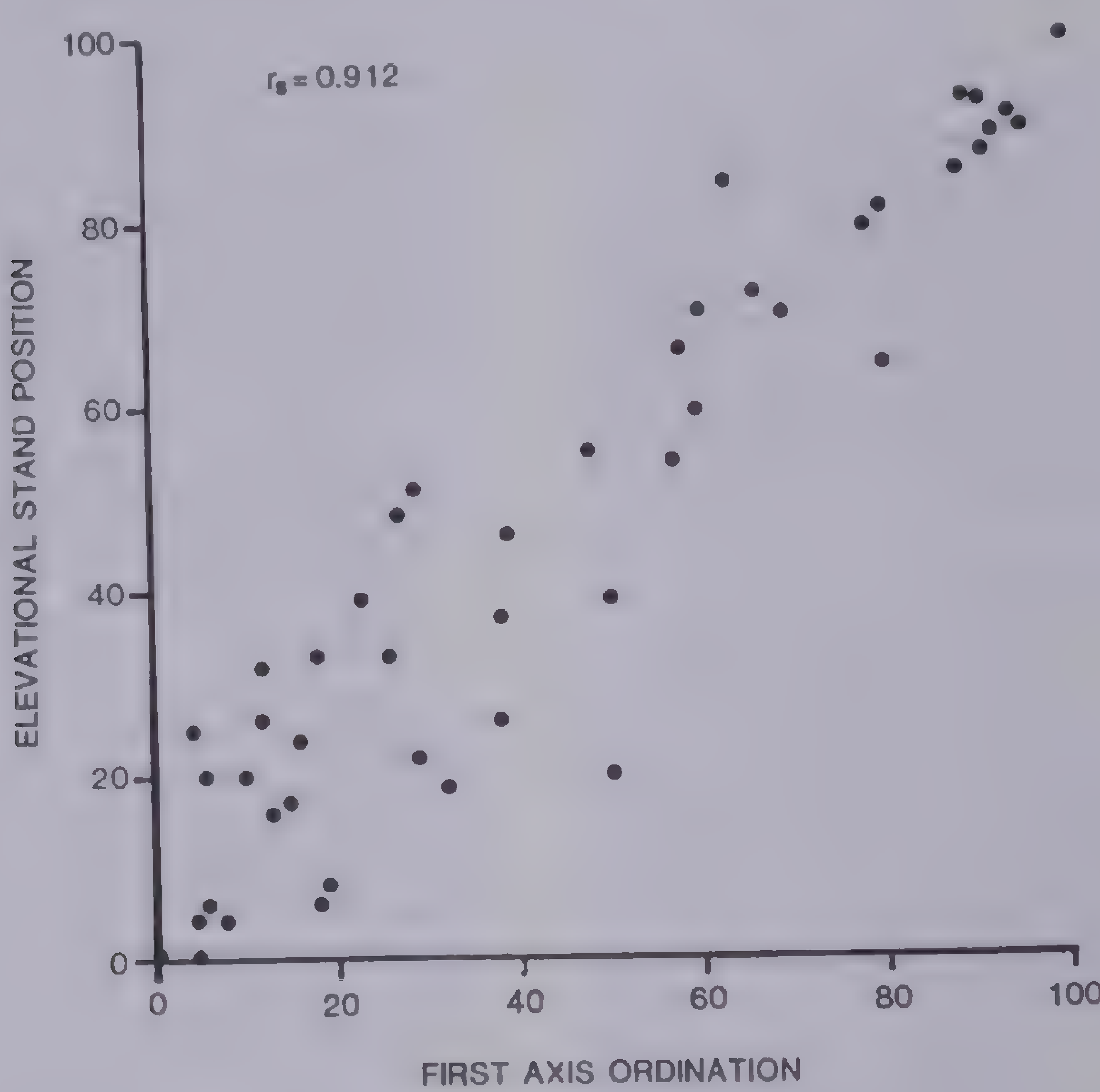

Figure 1.--Plot of RA first-axis ordination score of 46 riparian forest stands and stand elevation in the Tonto National Forest. r_s is Spearman rank correlation coefficient.

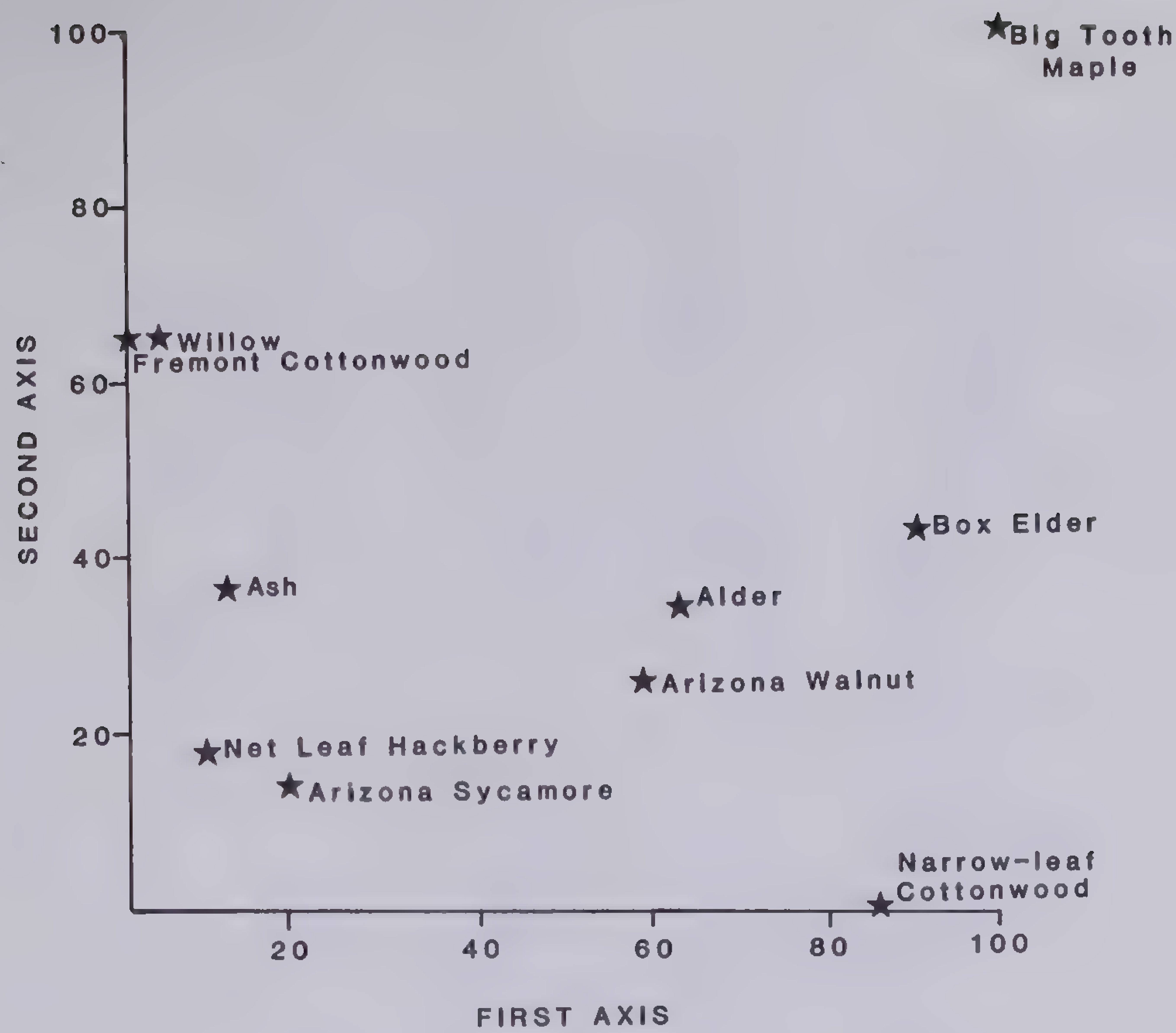

Figure 2.--Two-dimensional RA ordination of 10 deciduous broadleaf tree taxa from 46 riparian forest stands in central Arizona. Stars represent species ordination scores plotted against the first two ordination axes.

Cluster analysis of forest stands produced five groups (fig. 3). The arrangement of the species deciles above each stand in the cluster dendrogram illustrates the tree species composition of stands within the five clusters. The five clusters are interpreted as: (1) sycamore group, (2) Fremont cottonwood-willow group, (3) alder group, (4) narrow-leaf cottonwood group, and (5) maple group. These groups compare well with those obtained by the RA species ordinations (fig. 2). We circled those stands on the two-dimensional RA stand ordination plot that clustered together (fig. 3). This revealed five well-defined groups that corresponded with the RA species ordination groups (fig. 4).

From these results, we have chosen to define five major forest types within the mixed broadleaf riparian forests of the Tonto National Forest. They are distinguished by the presence or absence of characteristic dominant species. An examination of the average RIV of tree species within specified elevational intervals (table 1) indicates that four of the five types are defined by the most important tree species along the elevation gradient. These are Fremont cottonwood and the willows, Arizona sycamore, alder, and big tooth maple (as underlined in table 1). The general description of these forest types is as follows:

1. Fremont cottonwood-willow type - Usually found below 1250 m along perennial streams with either Fremont cottonwood, Goodding willow, or Bonpland willow as the dominant canopy species. In many stands these species occur as codominants. Velvet ash and Arizona sycamore are important associated tree species. Net leaf hackberry, alder, and Arizona walnut can be found within some stands but are of minor importance overall. Velvet mesquite (Prosopis velutina) and junipers are upland tree species which can occur

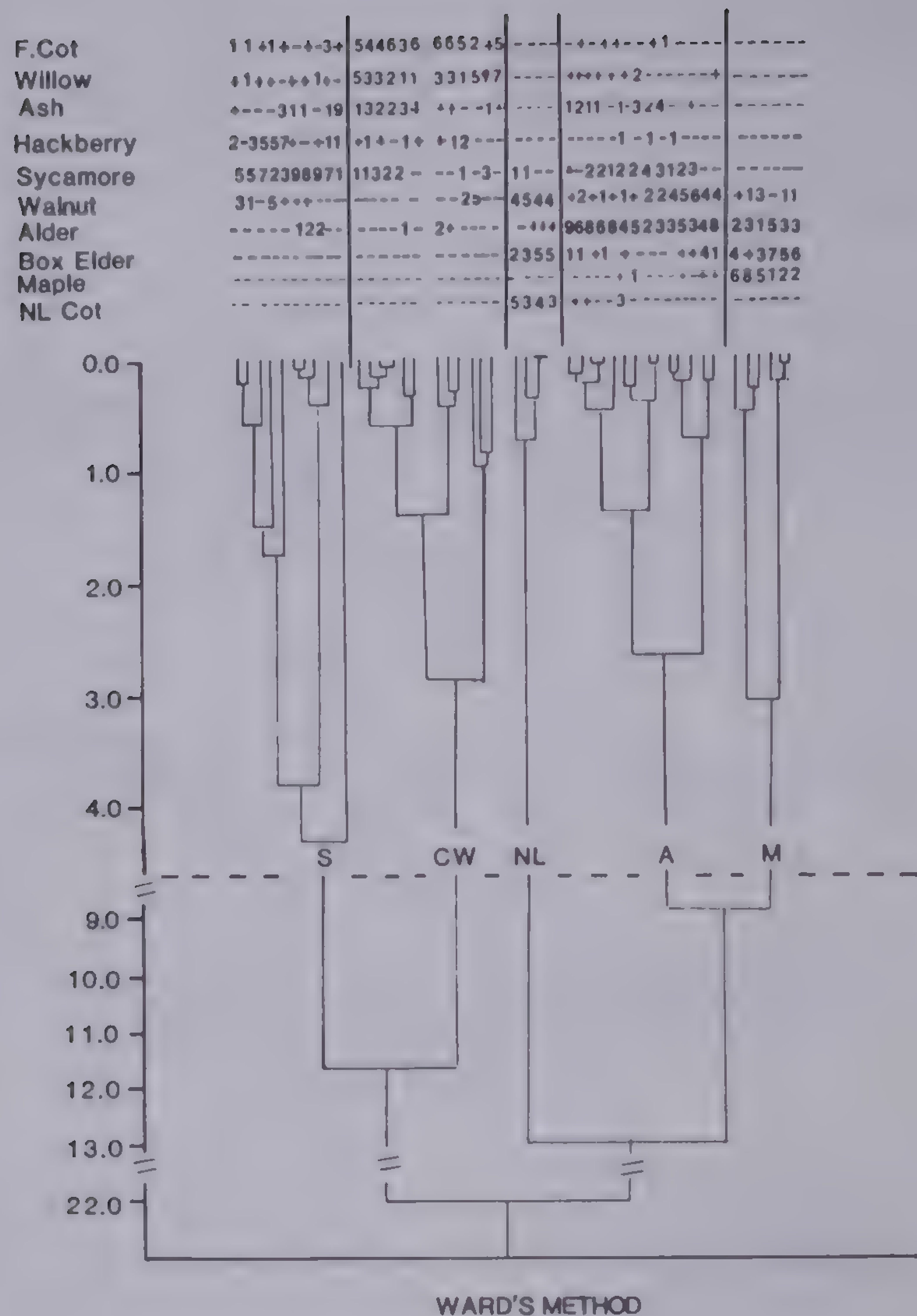

Figure 3.--Clusters dendrogram of 46 riparian forest stands in central Arizona which was derived from Ward's method. Species decile scores are arranged above each stand. Broken line represents five groups: S = sycamore; CW = Fremont cottonwood-willow; A = alder; NL = narrow-leaf cottonwood; M = maple.

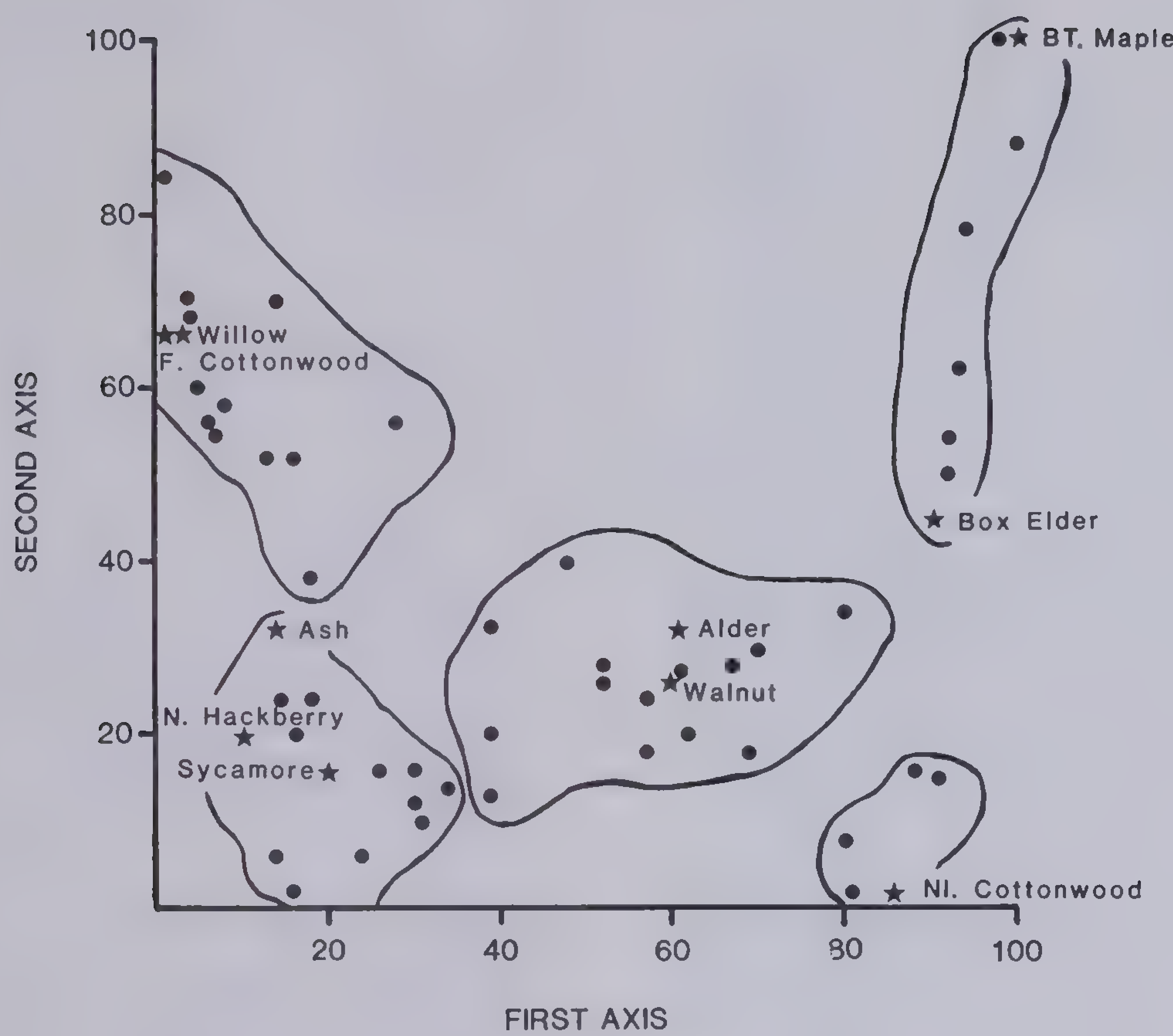

Figure 4.--Two-dimensional RA ordinations of 46 riparian forest stands (dots) in central Arizona and 10 major deciduous broadleaf tree taxa (stars) which occur in these stands. Circles enclose those stands which cluster together in figure 3. Stars represent species ordination scores and dots represent stand ordination scores plotted against the first two ordination axes.

Table 1.--Average RIV of deciduous broadleaf tree species within seven composite transects grouped according to elevation. The transects were composited along an elevational axis by the procedure given in Laurenzi (1982). Numbers in parentheses are elevational limits given in meters. Numbers below parentheses indicate number of stands within each transect.

Tree taxa	Composite elevational transect						
	I (763-871) 7	II (975-1095) 10	III (1169-1277) 6	IV (1369-1532) 6	V (1606-1705) 5	VI (1809-1923) 6	VII (1938-2077) 6
Fremont cottonwood	82.4	31.4	8.2	9.4	1.3	0.0	0.0
Willows	80.7	26.2	23.2	45.0	4.8	1.6	0.0
Net leaf hackberry	16.3	26.0	7.7	2.1	0.0	0.0	0.0
Velvet ash	45.0	54.1	43.5	40.3	6.9	0.0	0.0
Arizona sycamore	50.2	97.1	125.0	65.2	48.1	9.8	0.8
Arizona walnut	11.9	24.8	14.0	28.2	55.2	72.2	33.7
Arizona alder	4.5	23.3	62.4	98.0	126.9	99.9	83.9
Narrow-leaf cottonwood	0.0	0.0	0.0	1.2	39.1	34.8	17.3
Box elder	0.0	1.6	0.7	5.6	13.6	64.9	63.3
Big tooth maple	0.0	0.0	0.0	6.6	0.7	14.7	100.1

within the riparian forest but they generally compose less than 20% of total tree density (table 2). The upper elevation species, narrow-leaf cottonwood, box elder, and big tooth maple are absent from these assemblages.

As previously discussed, the interior riparian forest has been divided into two major vegetation types: cottonwood-willow and mixed broadleaf (Brown et al. 1977). The cottonwood-willow type defined here can generally be distinguished from the major vegetation type as defined by Brown et al. (1977) by the occurrence of other deciduous broadleaf trees as important associated tree species. However, as in any classification system, there is likely to be some overlap. As such, certain stands (studied here) which are composed exclusively of Fremont cottonwood and/or willows could also be classified apart from the mixed broadleaf series.

2. Sycamore type - Found at approximately the same and slightly higher elevations as the Fremont cottonwood-willow forests along perennial, intermittent, and semi-perennial streams. These forests are overwhelmingly dominated by Arizona sycamores, with net leaf hackberry, velvet ash, juniper, and Arizona white and Emory oaks (Quercus arizonica and Q. emoryi) occurring as important forest members in some stands. The latter three upland tree species compose on the average 36% of total tree density. Fremont cottonwood, willows, and alder are rare. The upper elevation species, box elder, narrow-leaf cottonwood, and big tooth maple, are absent.

3. Alder type - A diverse assemblage of tree species with all of the 11 species represented in at least one stand within this group. This type is generally denoted by the presence of alder as a canopy dominant, with velvet ash, Arizona sycamore, and Arizona walnut as important codominants. It is found along perennial streams at elevations between 1080 and 2000 m and spans a gradient in streamside conditions from lower elevation, low-gradient streams with substantial floodplain development to higher elevation streams of steep stream gradient with little floodplain development. Overall, upland tree species compose less than 25% of tree density, but this varies in accordance with stream gradient and/or elevation. Associated upland trees at lower elevations are junipers and Arizona white and Emory oaks. Ponderosa pine (Pinus ponderosa), Gambel oak (Quercus gambelii), New Mexican locust (Robinia neomexicana), white fir (Abies concolor), and Douglas fir occur at the higher elevations.

4. Narrow-leaf cottonwood type - Only four stands of this type were sampled in the study area. This type occurs between 1540 and 2000 m along perennial streams of moderate stream gradient and is distinguished by the presence of narrow-leaf cottonwood as a canopy dominant. Alder may be present in low density in some stands. Arizona walnut and box elder occur as codominants. Major upland tree species include junipers, Ponderosa pine, Gambel oak, and New Mexican locust, which compose between 25 and 60% of the total forest tree density.

Table 2.--Average densities of broadleaf deciduous riparian trees, associated upland trees, and environmental parameters of five riparian forest types in the Tonto National Forest.

Forest type	Density of broadleaf deciduous trees (n/ha)/(limits n/ha)	Density of upland trees (n/ha)/(limits n/ha)	Elevational limits (m)	Average stream gradient (m/m)
Fremont cottonwood-willow	358/185-704	59/0-138	763-1500	0.08
Sycamore	215/118-419	119/14-231	870-1428	0.11
Alder	335/147-619	127/0-437	1034-1869	0.15
Narrow-leaf cottonwood	289/232-332	257/75-501	1606-1980	0.10
Maple	240/125-486	274/186-435	1923-2077	0.31

5. Maple type - Occurs above 1800 m along perennial streams with a steep (relative to the other streams) stream gradient. This type is distinguished from the alder group by decreased importance of alder within the community and increased importance of box elder and big tooth maple as codominants with alder. Fremont cottonwood, willows, velvet ash, net leaf hackberry, and narrow-leaf cottonwood are absent from maple type communities. These forests are marginal as a distinct forest type, since they are generally dominated by upland mixed-conifer assemblages consisting of white fir, Douglas fir, and Ponderosa pine. These upland trees compose between 29 and 72% of total number of trees present. This type appears to be identical to Moir and Ludwig's (1979) Abies concolor/Acer grandidentatum habitat type.

DISCUSSION

In this study, ordinations of riparian forest stands generally produced an even continuum of stands and species populations along the elevational gradient. We suggest that the strong correlation between elevation and variation in species composition of Tonto National Forest riparian forest stands is due, in part, to the concordance between elevation and the physical variables within a river system, as well as to other well-known factors such as temperature and precipitation, which vary along such a complex gradient (Whittaker 1967).

Along the elevational gradient, the streamside environment can be thought to vary along an idealized stream profile. From source to mouth, the physical variables of a river system create a continuous gradient of physical conditions (Vannote et al. 1980). At the higher elevations, a stream's source, because of steep local relief, is almost completely erosional, and floodplain development is negligible. Although stream discharge is small, due to a small drainage area, discharge velocities are high, thus enabling sediments routed into the channels from side slopes to be moved downstream. Along the middle portion of the stream, as gradient begins to lessen, a narrow but distinct floodplain can be deposited from these upstream materials. At the downstream end, the gradient is the most gradual, and the floodplain reaches maximum development. Here erosion or sediment transportation usually gives way to deposition because of the diminished stream gradient and increased suspended load. Other factors which may vary in a downstream fashion are particle size of bed materials, which may decrease exponentially (Hack 1957), and magnitude and duration of flooding resulting from increasing watershed size.

Species responses to this gradient are directly related to individual life history attributes and their relationship to the streamside environment. Attributes likely to convey selective advantage upon species at various points along the gradient include flood tolerance, flood disturbance adaptations, and germination and early growth requirements as related to moisture availability (Reichenbacher 1983). Because the streamside environment varies in a continuous fashion, species populations also form a complex continuum of broadly overlapping distributions. The inclusiveness and the limits of each type, therefore, are unavoidably arbitrary.

Although differences in composition among forest types in this study are clearly related to site factors that vary along the elevational gradient, it must be emphasized that the factors that control stream dynamics and resultant land forms are extremely complex (Leopold et al. 1964). At the lower elevations there is an indication that the occurrence of the Fremont

cottonwood-willow type versus the sycamore type is related to local fluvial landforms rather than to elevation. The former type generally occurs in areas of perennial flow, often on bedrock, whereas the sycamore type is often found along streams on valley fill where streamflow is ephemeral or intermittent. In the higher-elevation stands, apart from elevation, the occurrence of maple versus narrow-leaf cottonwood types is related to stream gradient. The maple type generally occurs along steep, mountaintop perennial streams, whereas narrow-leaf cottonwood types occur along perennial streams situated in high elevation basins. The rarity of narrow-leaf cottonwood in the study area was probably related to the infrequent occurrence of high elevation basin topography. North of the Tonto on the Colorado Plateau, at elevations from 1500 to 2460 m, perennial streams are dominated in large part by narrow-leaf cottonwood. This area is characterized by extensive high elevation basin topography.

The basic units we have described are called "types," and collectively they form an "ecological series" after Brown (1978) and Whittaker (1978). These forest types have been loosely defined by the presence or absence of characteristic dominant species. Brown (1978) has suggested that these "associations" or "types" within the mixed broadleaf series be considered generally equivalent to habitat-types as outlined by Daubenmire (1976) and Pfister et al. (1977). The classification we present, however, is not analogous, in our opinion, to the concept of habitat type as related to potential climax vegetation. Accordingly, we do not interpret these descriptors of types as climax dominants (sensu Daubenmire 1976). We feel that due to the dynamic and complex nature of riparian ecosystems, the habitat-type is not applicable to riparian forests. With this in mind, we emphasize the importance of stochastic variation in tree species composition of mixed broadleaf forests at any particular point in time or space. Accordingly, we recognize the difficulty in precisely describing forest types as we have defined them. We conclude by suggesting the use of the simple key in table 3 in conjunction with our previous descriptions to aid the land manager in reliable field identification of these types.

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Table 3.--A key to the forest types belonging to the mixed broadleaf series of interior deciduous riparian forest in the Tonto National Forest.

1. Narrow-leaf cottonwood or big tooth maple present as one of the dominant forest trees.....................................4

1′. Narrow-leaf cottonwood or big tooth maple not present as dominant forest trees......2

  2. Arizona sycamore overwhelmingly dominant, other deciduous broadleaf trees present but clearly of lesser importance in the forest....B. Sycamore type

  2′. Arizona sycamore absent or if present other deciduous broadleaf trees of equal importance or nearly so.........3

3. Alder clearly one of the dominant forest trees.........................C. Alder type

3′. Alder absent or of relatively minor importance; Fremont cottonwood, Goodding willow or Bonpland willow present singly or together as dominant forest trees......................A. Fremont cottonwood-willow type

  4. Narrow-leaf cottonwood present as one of the dominant forest trees.....................D. Narrow-leaf cottonwood type

  4′. Big tooth maple present as one of the dominant forest trees.....E. Maple type

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Soil and Vegetation Changes Along a Climatic Gradient in the Southern Sangre de Cristo Mountains [1]

Jimmy M. Gass[2]

Abstract.--Gradient analysis was applied to soils and vegetation changes in the southern Sangre De Cristo Mountains. Ten vegetative subseries representative of climatic climax were differentiated from a gradient where mean annual soil temperature decreased from 13ºC to -1ºC as mean annual precipitation increased from 30 cm to 90 cm. These were combined with soils classified to the family or subgroup (modified) level of soil taxonomy to form terrestrial ecosystems.

Climatic data, kind and amount of vegetation, kinds of soil and productivity estimates were presented in a format of columns and rows. The columns contain all observed, measured or interpreted information relevant to a specific climate. The rows depict changes in a particular characteristic as the climate changes from semi-arid and cool to sub-humid and cold.

Soil and vegetation have been correlated with certain climatic conditions, and the changes noted over an elevational gradient of 2100 meters in the southern Sangre De Cristo Mountains. This paper deals with the gradient development process, but does not discuss the theory associated with the process.

Initially, kind and amount of vegetation are plotted against elevation, and vegetative subseries are established. In the southern Sangre De Cristo Mountains (high sun, cool) ten subseries were recognized for climatic climax as follows:

Elevation

Bogr2 Hija	Jumo	Pied Jumo	Pied Jumo Quga	Pipo Pied Quga	Pipo Quga	Abco Psmeg Pipo Quga	Pien Ablaa Abco Psmeg	Pien Ablaa Potr5	Arco5 Poal2 Arars	SS
1850	2000	2150	2300	2450	2500	2900	3200	3500	3800	ME(m)

Certain measured or inferred climatic information is then integrated into the developing gradient.

Climate

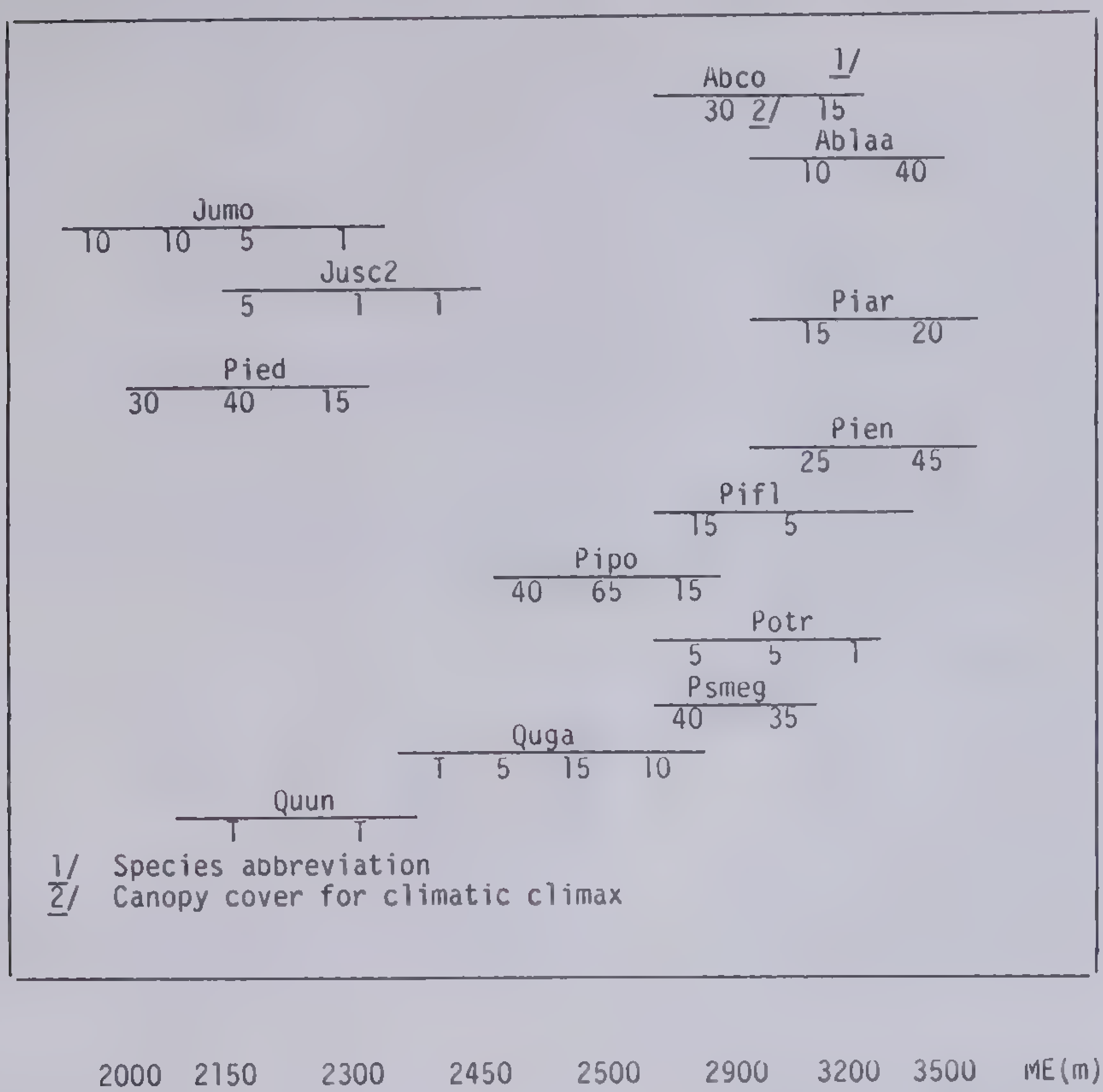
Bogr2 Hija	Jumo	Pied Jumo	Pied Jumo Quga	Pipo Pied Quga	Pipo Quga	Abco Psmeg Pipo Quga	Pien Ablaa Abco Psmeg	Pien Ablaa Potr5	Arco5 Poal2 Arars	SS
1850	2000	2150	2300	2450	2500	2900	3200	3500	3800	ME(m)
13	12	10	9	8	7	6	3	1	-1	MAST (°C)
-	-	-	-	13	12	10	7	3	4	MSST (°C)
30	35	40	45	50	55	65	75	85	90	MAP (cm)

[1]Paper presented at the Workshop on Southwestern Habitat Types, Albuquerque, NM, April 6-8, 1983.

[2]Soil Scientist, USDA Forest Service, Soil and Water Staff Unit, Southwestern Region, Albuquerque, NM.

Figure 1 depicts the manner in which kind and amount of trees are correlated with elevation along a climatic gradient. Similar analyses are done using shrubs, forbs and grasses.

Figure 1. Kind and amount of trees plotted against elevation.



Climate is an integral part of soil taxonomy thus, correlations between vegetation and soil moisture and temperature regimes are apparent.

Soil temp./moist. regimes

Bogr2 Hija	Jumo	Pied Jumo	Pied Jumo Quga	Pipo Pied Quga	Pipo Quga	Abco Psmeg Pipo Quga	Pien Ablaa Abco Psmeg	Pien Ablaa Por5	Arco5 Po212 Arars	SS
1850	2000	2150	2300	2450	2500	2900	3200	3500	3800	ME(m)
13	12	10	9	8	7	6	3	1	-1	MAST(°C)
-	-	-	-	13	12	10	7	3	4	MSST(°C)
30	35	40	45	50	55	65	75	85	90	MAP(cm)
Mesic	Mesic	Mesic	Mesic	Frigid	Frigid	Frigid	Cryic	Cryic	Pergelic	Soil Temp. Regime
Ustic	Ustic	Ustic	Ustic	Ustic	Ustic	Udic	Udic	Udic	Udic	Soil Moist. Reg.

Climate is diagnostic at different categories of soil taxonomy. It is incorporated in all taxonomic names at the Subgroup and below. For example, Inceptisols (Order) and Ochrepts (Suborder) may have any temperature regime and any moisture regime except aquic. Ustochrepts (Great group), however, must have an ustic moisture regime and a temperature regime warmer than cryic. Aridic Ustochrepts (Subgroup) have an ustic moisture regime which is marginal to an aridic moisture regime.

Combining a knowledge of soil taxonomy and vegetative indicators of climate (temperature and precipitation), certain relationships between soil, vegetation and climate can be established as follows:

Integration of soil subgroups

Bogr2 Hij2	Jumo	Pied Jumo	Pied Jumo Quga	Pipo Pied Quga	Pipo Quga	Abco Psmeg Pipo Quga	Pien Ablaa Abco Psmeg	Pien Ablaa Potr5	Arco5 Poal2 Arars	SS
Arid Haplus.	Typic Haplus.	Typic Haplus.	Typic Haplus.	Typic Eutrob.	Typic Eutrob.	Eutric Glossb.	Typic Cryobo.	Typic Cryobo.	-	Subgroup Great groups
Aridic Ustoch. Mesic Ustic	Typic Ustoch. Mesic Ustic	Typic Ustoch. Mesic Ustic	Typic Ustoch. Mesic Ustic	Udic Ustoch. Frigid Ustic	Udic Ustoch. Frigid Ustic	Typic Dystrc. Frigid Udic	Dystric Cryoch. Cryic Udic	Dystric Cryoch. Cryic Udic	Pergelic Cryoch. Pergelic Udic	Subgroup (Inceptisols) Soil Temp. Regime Soil Moist. Reg.

Examination of this information shows soils of identical classification associated with more than one vegetative Subseries. Typic Haplustalfs, for example, occur with three different Subseries: Jumo, Pied/Jumo and Pied/Jumo/Quga.

A means of identifying a one-to-one relationship between soil and vegetation is necessary. Subgroup modifiers were developed for this purpose. A number "0" following the Subgroup indicates the central concept of the Subgroup. A "-1" indicates warmer and drier conditions than the central concept. A "+1" indicates cooler and/or more moist conditions.

The developing gradient now appears as follows:

Subgroup modifier

Bogr2 Hija	Jumo	Pied Jumo	Pied Jumo Quga	Pipo Pied Quga	Pipo Quga	Abco Psmeg Pipo Quga	Pien Ablaa Abco Psmeg	Pien Ablaa Potr5	Arco5 Poal2 Arars	SS
1850	2000	2150	2300	2450	2500	2900	3200	3500	3800	ME(m)
13	12	10	9	8	7	6	3	1	-1	MAST(°C)
-	-	-	-	13	12	10	7	3	4	MSST(°C)
30	35	40	45	50	55	65	75	85	90	MAP(cm)
Mesic	Mesic	Mesic	Mesic	Frigid	Frigid	Frigid	Cryic	Cryic	Pergelic	Soil Temp. Regime
Ustic	Ustic	Ustic	Ustic	Ustic	Ustic	Udic	Udic	Udic	Udic	Soil Moist. Reg.
Aridic Haplus. 0	Typic Haplus. -1	Typic Haplus. 0	Typic Haplus. +1	Typic Eutrob. -1	Typic Eutrob. 0	Eutric Glossb. 0	Typic Cryobo. -1	Typic Cryobo. 0	Pergelic Cryoch. 0	

The final product is a document which shows the interrelationships between soil, vegetation and climate. Interpretations relevant to use and management of the various resources can be made from mapped phases of terrestrial ecosystems.

Primary Climatic Gradients in New Mexico and Arizona[1]

Owen Carleton and Gassaway Brown[2]

Abstract.--The conceptual basis is given for recognizing terrestrial ecosystems as interacting expressions of soil and vegetation governed primarily by climate. Climates can be described as continua of temperature and moisture along which terrestrial ecosystems differentiate. The Southwestern Region can be partitioned into four generalized climatic subregions described in this paper. These conceptual divisions are displayed as tabular columns in which climatic data, vegetation (as climatic Subseries), and soils (as Subgroups with modifiers) are displayed. Each column in any particular climatic region is essentially a biological life zone. This paper descibes 15 distinctive life zones from the hottest of desert regions to the coolest alpine tundras of the Southwest. In the real world numerous variations of these four basic gradients can be defined locally, but any variant gradient can be related to portions of the four primary climatic gradients.

Introduction

Climate is considered as the primary force in determining a particular terrestrial ecosystem (TE). "The interplay of climate, soil and vegetation is often represented by a triangle:

It implies that climate affects soil and vegetation independently, that soil influences vegetation, and that vegetation reacts upon soil." (Jenny H., 1958 p. 5).

Climatic boundaries are statistically determined boundaries and as such cannot be observed nor mapped on the ground. "A climatic boundary on a map indicates only the mean position of numerous individual climatic-year boundaries, which typically depart by hundreds of miles from the mean." (Trewatha, 1968, pp 244-245).

Climate, while of prime importance, is an illusive parameter. Problems in direct measurement and correlation with all TE are insurmountable. A reasonable alternative to direct measurement and correlation of climate is to recognize the effect of climate through vegetation and soils.

Process

The process used in determining the primary climatic gradient is dependent upon the following statements:

1. "That (1) the lower elevational limit of a given species of plant on the moisture-temperature gradient is controlled by deficient moisture, and (2) that the upper elevational limit is controlled by deficient heat. It is beyond reasonable doubt that these findings are correct (Daubenmire, 1934a, 1959; Lindsey, 1951)." (Lowe, C.H., 1964, p. 89).

2. "Climates are continua and none but arbitrary boundaries can be recognized unless one uses the distribution of living organisms to show critical points along climatic gradients where physiological limits of tolerance are reached." (Daubermire, R., 1968, p. 239).

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[1]Paper presented at the Workshop on Southwestern Habitat Types, Albuquerque, New Mexico, April 6-8, 1983.

[2]Assistant Director, Soils and Water Staff Unit, Region 3 and Regional Geologist, Region 3 US Forest Service.

3. "With the climatic climax reflecting climatic influence most directly it becomes the best criterion of the extent of biologically equivalent macroclimates. It is therefore feasible to divide the land surface into mutually exclusive areas characterized by climatic climaxes, for only one such type of vegetation is found in one area." (Daubermire, R., 1968, p. 239-240).

4. "For a given region it is convenient, although somewhat arbitrary to recognize (1) a single climatic climax, which is in an equilibrium with the general climate, and (2) a varying number of edaphic climaxes, which are modified by local conditions of the substrate. The former is the theoretical community toward which all successional development in a given region is tending; it is realized where physical conditions of the substrate are not so extreme as to modify the effects of the prevailing regional climate. Succession ends in an edaphic climax where topography, soil, water, fire or other disturbance are such that the climatic climax cannot develop." (Odum, E.P., 1971, p 264).

5. "Such patterns imply a gradual and progressive change in the structure of vegetation from one environmental extreme to another, a continuum in which discrete subdivisions do not exist. Nonetheless, the existence of the continuum does not preclude the recognition of major vegetative types over a broader area of the same region (Figure 5-17) or on the very broad scale of the biome (Figure 5-1)" (Kormondy, E.J., 1969, pp. 138-139).

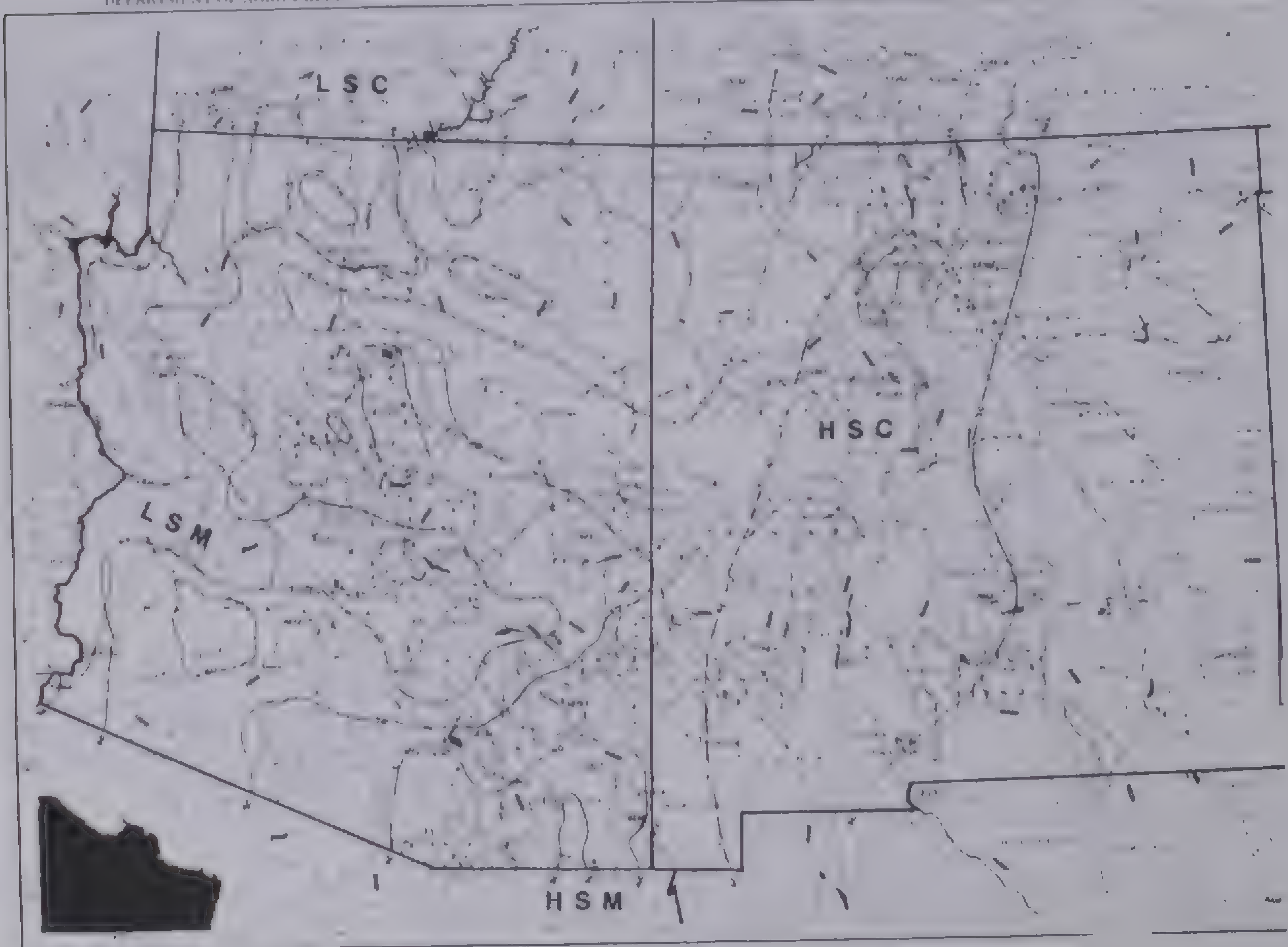
6. "Every plant is a measure of the conditions under which it grows. To this extent it is an index of soil and climate, and consequently an indicator of the behavior of other plants and animals in the same spot." (Clements, F.E., 1920, p. 3).

Figure 1 is the map used in depicting generalized climatic subregions. Approximate location of surveys is correlated with a climatic subregion. This then allows for recognition of the primary climatic gradient appropriate for that survey area.

FIGURE 1

UNITED STATES DEPARTMENT OF AGRICULTURE

GEOGRAPHIC DISTRIBUTION OF TERRESTRIAL ECOSYSTEMS

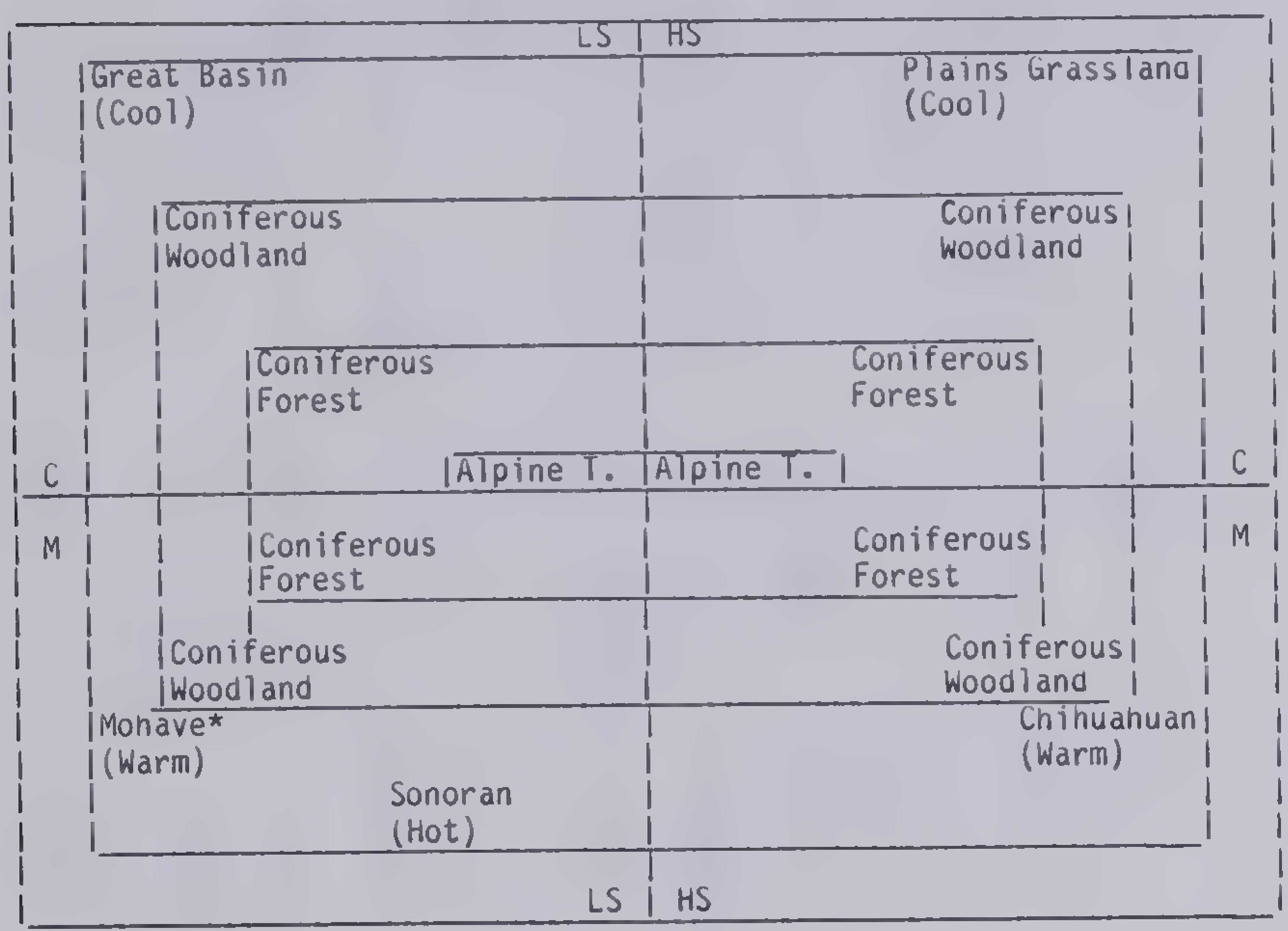


The following table contains criteria used in recognizing generalized climatic subregions.

Table 1. Criteria for determing climatic subregions.

Season with greater than one-half of annual precipitation	Winter Temperature Adj.	STR (column 10)	Indicator Plants (Not an inclusive listing)
HSM--High sun (HS) 01 April to 30 Sept.	Mild (M)	Mesic	Quhy, Quar, Qugr3, Arpu5 (evergreen)
HSC--High sun (HS) 01 April to 30 Sept.	Cold (C)	Frigid	Quga, Quun (deciduous)
LSM--Low sun (LS) 01 Oct. to 31 Mar.	Mild (M)	Mesic	Quar, Qutu2, Arpu5 (evergreen)
LSC--Low sun (LS) 01 Oct. to 31 Mar.	Cold (C)	Frigid	Quga, Artr2 (deciduous/evergreen)

Figure 2 illustrates the conceptual basis for table 2. Table 2 contains the summary for the four major climatic gradients. Information contained in table 2 is used to formulate terrestrial ecosystems unique to a climatic regime (column). Phases of terrestrial ecosystems are mapped in the field and interpretated in reports.



* To be incorportated into "Primary Climatic Gradients as LSM counter part to HSM Chihuahuan Desert.

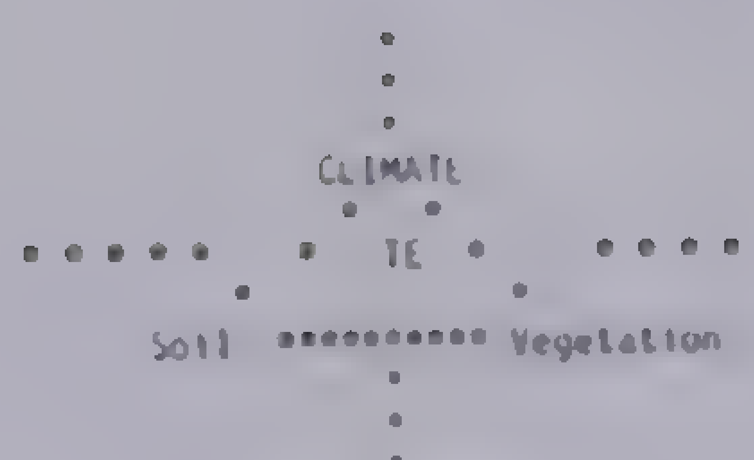
Figure 2. Conceptual relationship between major climatic gradients.

Table 2. Summary of the four major climatic gradients of Arizona and New Mexico.

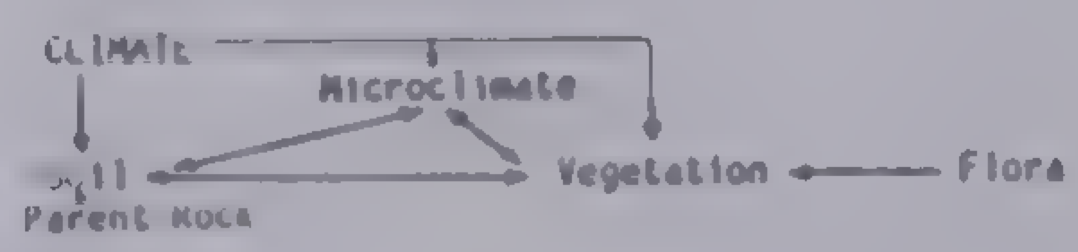
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
Desert	Desert	Desert	Desert	Desert	SuInd. GsInd.	WdInd.	WdInd.	WdInd.	Forest	Forest	Forest	Forest	Forest	Alpine T.	Formation (Biomes)		
				56	54(53)	52	50	48(48)	44(45)	42(41)	40(41)	38(37)	34	30	MAST 1/	deg. F	LSC
				14	13	11	10	9	7	6	4	3	1	-1		deg. C	
									56	54	50	44	38	40	MSST	deg. F	
									13	12	10	7	3	4		deg. C	
				8	10	12	14	16	18	20	24	28	32	36	MAP	in.	
				15	25	30	35	40	45	50	60	70	80	90		cm	
				5500	6000	6500	7000	7500	8000	8500	9500	10500	11500	12500	ME	ft	
				1700	1850	2000	2150	2300	2450	2500	2900	3200	3500	3800		m	
				160	150(151)	140	130(126)	120	110	100	80	60	40	20	FFP	no. days	
				Mesic	Mesic	Mesic	Mesic	Mesic	Frigid	Frigid	Frigid	Cryic	Cryic	Pergelic	STR		
					56	54(54)	52(51)	50	46	44(44)	42(42)	38(38)	34(35)	30(32)	MAST	deg. F	HSC
									8	7	6	3	1	-1		deg. C	
									56	54	50	44	38	40	MSST	deg. F	
									13	12	10	7	3	4		deg. C	
					12	14	16	18	20	22	26	30	34	36	MAP	in.	
					30	35	40	45	50	55	65	75	85	90		cm	
					6000	6500	7000	7500	8000	8500	9500	10500	11500	12500	ME	ft	
					1850	2000	2150	2300	2450	2500	2900	3200	3500	3800		m	
					170	160	150(153)	140	130	120	100	70	50	20	FFP	no. days	
					Mesic	Mesic	Mesic	Mesic	Frigid	Frigid	Frigid	Cryic	Cryic	Pergelic	STR		
			66	62	60	58	56	54	50	48	46	44	40		MAST	deg. F	HSM
			19	17	15	14	13	12	10	9	8	7	4			deg. C	
									58	56	52	46	40		MSST	deg. F	
									14	13	11	8	4			deg. C	
			10	12	14	16	18	20	22	24	28	32	36		MAP	in.	
			25	30	35	40	45	50	55	60	70	80	90			cm	
			3500	4500	5000	5500	6000	6500	7000	7500	8500	9500	10500		ME	ft	
			1000	1350	1550	1700	1850	2000	2150	2300	2500	2900	3200			m	
			230	210	190	180	170	160	150	140	120	100	80		FFP	no. days	
			Thermic	Thermic	Thermic	Mesic	Mesic	Mesic	Mesic	Mesic	Frigid	Cryic	Cryic		STR		
74	72	70	68	64	62	60	58	56	52	50	48				MAST	deg. F	LSM
23	22	21	20	18	17	15	14	12	11	10	9					deg. C	
									60	58	54				MSST	deg. F	
									15	14	13					deg. C	
6	8	10	12	14	16	18	20	22	24	26	30				MAP	in.	
15	20	25	30	35	40	45	50	55	60	65	75					cm	
1000	1000	1500	2500	3500	4000	4500	5000	5500	6000	6500	7000				ME	ft	
300	300	450	750	1000	1200	1350	1550	1700	1850	2000	2150					m	
310	290(290)	270	250	230	210	200	190	180	170	160	150				FFP	no. days	
Hyperth.	Hyperth.	Thermic	Thermic	Thermic	Thermic	Thermic	Mesic	Mesic	Mesic	Mesic	Mesic				STR		
Aridic	Aridic	Aridic	Aridic	Aridic	Ustic	Ustic	Ustic	Ustic	Ustic	Ustic	Udic	Udic	Udic	Udic	SMR		LSC LSM HSC HSM
				Atco Hija Bogr2	Artr2 Hija Bogr2	(Juos) (Jumo) Artr2	Pied (Jude2) (Juos) (Jumo) Artr2	Pied (Jude2) (Juos) (Jumo) Quga Artr2	Pipo Pied (Jude2) (Juos) (Jumo) Quga Artr2	Pipo Quga	Abco Psmeg Pipo Quga	Pien (Abla) (Ablaa) Abco Psmeg	Pien (Abla) (Ablaa) Potr5	Arco5 Poal2 Arars Sefr	SS (Climatic)		LSC
					Hija Bogr2 Boer4	(Jude2) (Juos) (Jumo)	Pied (Jude2) (Juos) (Jumo)	Pied (Jude2) (Juos) (Jumo) Quga (Quun)	Pipo Pied (Jude2) (Juos) (Jumo) Quga (Quun)	Pipo Quga (Quun)	Abco Psmeg Pipo (Pist) Quga	Pien Ablaa Abco Psmeg	Pien Ablaa Potr5	Arco5 Poal2 Arars	SS (Climatic)		HSC
			Prgigl (Prve) Fice Boer4	Prgigl (Prve) Boer4	Prgigl (Prve) Bogr2 Boer4 (Bora)	(Quoo) Jude2 (Jumo) (Juer)	(Pidi) (Pied) Jude2 (Jumo) (Quar) (Quyr3) (Arpu5)	(Pidi) (Pied) Jude2 (Jumo) (Arar) (Arte) (Quar) (Quyr3) (Arpu5)	Pipo (Pipoa) (Picn) Pidi) (Pied) Jude2 (Arar) (Arte) (Quar) (Qugr3) (Arpu5)	Pipo (Pipoa) (Quhy) (Arar) (Arte)	Abco Psmeg Pipo Pist Quga	(Pien) Ablaa Abco Psmeg	(Pien) Ablaa Potr5		SS (Climatic)		HSM
Frde Frdu	Cegi Olte Cemi2 Frde	Cegi Cemi2 Frde	Cegi Cemi2 Prve Boer4	Prve Beha Boer4	Prve Beha Bogr2 Boer4	Juos (Juer) (Jumo) Prve Qutu2	Pimo Juos (Jumo) Qutu2 Arpu5	Pimo Jude2 Juos (Jumo) Quar Qutu2 Arpu5	Pipo Pimo Jude2 Juos Quar Arpu5	Pipo Jude2 Quar Arpu5	Abco Psmeg Pipo Jude2 Quar Arpu5				SS (Climatic)		LSM

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
															LSC
				0/20 2/40	0/30 2/55	10/25 2/45	40/20 2/30	50/15 3/15	55/10 3/15	65/15 10/10	85/20 15/3	90/22 15/0	85/50 4/0		Canopy cover % Trees/shrubs Forbs/graminoids
				Ustalfic Haplarg.	Aridic Haplust.	Typic Haplust.	Typic Haplust.	Typic Haplust.	Typic Eutrobo.	Typic Eutrobo.	Eutric Glossob.	Typic Cryobor.	Typic Cryobor.		
															0-40% slopes 50 to 100cm depth 100cm+ SCF - 25%
				[illegible]	0	[illegible]	20	30	50	70	80	75	70		Litter %
				60	50	45	40	35	25	10	0	0	0		Bare Soil %
				40	50	50	40	35	25	20	20	25	30		Vegetation (BA) %
				400	600	650	700	750	800	500	400	300	100		Herbage lb/ac/yr
				200	300	250	200	175	175	250	150	75	50		Forage lb/ac/yr
				300	600	700	1200	1600	2000	2500	3500	4000	3000		Forage M. lb/ac/yr
									Pipo/45	Pipo/65	Abco/65 Psmeg/65 Pipo/65	Pien/70 Abco/65 Psmeg/65	Pien/75		50 to 100 cm depth Species/SI
									Pipo/55	Pipo/70	Abco/70 Psmeg/70 Pipo/65	Pien/70 Abco/65 Psmeg/65	Pien/75		100cm+ Species/SI
						(Jude2) (Juos) (Jumo)	Pied (Jude2) (Juos) (Jumo)	Pied (Jude2) (Juos) (Jumo)	Pied (Jude2) (Juos) (Jumo)						Species
						2	10	18	10						Volume cd/ac
															HSC
					0/0/ 2/70	10/1/ 2/60	40/4/ 2/30	50/4/ 3/15	55/4/ 3/15	65/15/ 10/10	85/20/ 15/3	90/20/ 15/0	85/50/ 4/0		Canopy cover % Trees/Shrubs Forbs/Graminoids
					Aridic Haplust.	Typic Haplust.	Typic Haplust.	Typic Haplust.	Typic Eutrobo.	Typic Eutrobo.	Eutric Glossob.	Typic Cryobor.	Typic Cryobor.		
															0-40% slopes 50 to 100cm depth 100cm+ SCF - 25%
					[illegible]	5	20	30	50	70	80	75	70		Litter %
					50	45	40	35	25	10	0	0	0		Bare Soil %
					50	50	40	35	25	20	20	25	30		Vegetation (BA) %
					600	650	700	750	800	500	400	300	100		Herbage lb/ac/yr
					600	500	275	175	175	250	150	75	50		Forage lb/ac/yr
					600	700	1200	1600	2000	2500	3500	4000	3000		Forage M. lb/ac/yr
									Pipo/45	Pipo/65	Abco/65 Psmeg/65 Pipo/60	Pien/70 Abco/65 Psmeg/65	Pien/75		50 to 100cm depth Species/SI
									Pipo/55	Pipo/70	Abco/70 Psmeg/70 Pipo/65	Pien/70 Abco/65 Psmeg/65	Pien/75		100cm+ Species/SI
						(Jude2) (Juos) (Jumo)	Pied (Jude2) (Juos) (Jumo)	Pied (Jude2) (Juos) Jusc2 (Jumo)	Pied (Jude2) Jusc2						Species
					0	2	10	18	10	0					Volume cd/ac
															HSM
			0/20 T/20	0/15 T/30	0/10 2/40	10/15 2/30	40/20 2/20	50/25 3/10	55/15 3/10	65/20 10/10	85/25 15/3	90/20 15/0	85/50 4/0		Canopy cover % Trees/Shrubs Forbs/Graminoids
			Typic Haplarg.	Ustalfic Haplarg.	Aridic Haplust.	Typic Haplust.	Typic Haplust.	Typic Haplust.	Udic Haplust.	Udic Haplust.	Eutric Glossob.	Typic Cryobor.	Typic Cryobor.		
															0-40% slopes 50 to 100cm depth 100cm+ SCF-25%
			0	0	0	5	20	30	50	70	80	75	70		Litter %
			70	60	50	45	40	35	25	10	0	0	0		Bare Soil %
			30	40	50	50	40	35	25	20	20	25	30		Vegetation (BA) %
			200	400	600	650	700	750	800	500	400	300	100		Herbage lb/ac/yr
			100	300	400	300	150	100	100	150	100	75	50		Forage lb/ac/yr
			150	300	600	700	1200	1600	2000	2500	3500	4000	3000		Forage M. lb/ac/yr
									Pipo/45	Pipo/65	Abco/65 Psmeg/65 Pipo/60	Pien/70 Abco/65 Psmeg/65	Pien/75		50 to 100cm depth Species/SI
									Pipo/55	Pipo/70	Abco/70 Psmeg/70 Pipo/65	Pien/70 Abco/65 Psmeg/65	Pien/75		100cm+ Species/SI

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
						(Quob) Jude2 (Jumo) (Juer)	(Pidi) (Pied) Jude2 (Jumo) (Quar) (Quga3)	(Pidi) (Pied) Jude2 (Jumo) (Quar) (Quga3)	(Pidi) (Pied) Jude2 (Jumo) (Quar) (Quga3)						Species
						2	10	18	10						Volume cd/ac
															LSM
															Canopy cover %
0/20	2/25	7/30	3/25	0/20	0/15	10/25	40/30	50/40	55/20	65/15	85/20				Trees/Shrubs
0/0	0/0	T/5	T/10	T/20	2/30	2/20	2/10	3/5	3/5	10/10	15/3				Forbs/Graminoids
Typic Haplarg.	Typic Haplarg.	Typic Haplarg.	Typic Haplarg.	Ustalf. Haplarg.	Aridic Haplust.	Typic Haplust.	Typic Haplust.	Typic Haplust.	Udic Haplust.	Udic Haplust.	Typic Haplud.				
															0-40% slopes 50-100 cm depth 100 cm+ SCF - 25%
0	0	0	0	0	0	5	20	30	50	70	80				Litter %
95	90	80	70	60	50	45	40	35	25	10	0				Bare Soil %
5	10	20	30	40	50	50	40	35	25	20	20				Vegetation (BA) %
25.	50	100	200	400	600	650	700	750	800	500	400				Herbage lb/ac/yr
0	0	50	100	200	300	200	100	50	50	50	50				Forage lb/ac/yr
0	0	50	150	300	600	700	1200	1600	2000	2500	3500				Forage lb/ac/yr
									Pipo/55	Pipo/70	Abco/70 Psmeg/70 Pipo/65				100cm+ Species/SI
						(Juos) (Juer) (Jumo)	Pimo Juos) (Jumo)	Pimo Jude2 Juos (Jumo) Quar	Pimo Jude2 Juos Quar						Species
						2	10	18	10						Volume cd/ac



(Hans Jenney)
1958, p. 5



(Heinrich Walter)
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1/ Abbreviations are as follows:

- MAST Mean annual soil temperature
- MSST Mean summer soil temperature
- MAP Mean annual precipitation
- ME Mean elevation
- FFP Freeze free period
- STR Soil temperature regime
- SMR Soil moisture regime
- SS Subseries (a rank of vegetation taxonomy).

A Series Vegetation Classification for Region 3 [1]

W.H. MOIR [2]

Abstract.--17 climatic and 23 "non-climatic" series are proposed and briefly described for lands in National Forests and Grasslands of Region 3 (mostly Arizona and New Mexico). These are broadly conceived series and may not yet be comprehensive especially concerning some of the minor series.

The series has been defined as all plant associations having the same potential dominant species at climax (Layser and Schubert 1979). In this paper I propose a series level classification for the major and minor vegetation on National Forests and Grasslands in Region 3. I also enclose a vegetation taxonomy and hierarchy for Arizona and New Mexico to show the relationship between series (as used in this report), subseries as inventoried and classified within the Region's Terrestrial Ecosystem Survey (TES), and plant associations as defined by habitat type studies in Arizona and New Mexico.

The series herein reported are mostly provisional. Except for coniferous forests, they are not data-based but gleaned mostly from literature or from experience with our inventoried vegetation subseries. Therefore, I simply interpreted these series on a broad basis. Table 1 gives these series according to whether they are primarily climatic (i.e. reflecting macroclimates on vadose soils), major phreatic, or departures from climatic in special environments (edaphic, topoedaphic, grazing climaxes, minor phreatic, etc.).

Although I have tried to be very general (a lumper) in the concept of series, this classification is not yet comprehensive. I have not included series perhaps more important on lands administered by other public or private agencies (e.g. Ouercus havardii series). The series indicated as minor in table 1 on national Forest lands, such as Larrea divaricata series, are of course major in the Southwest in general. There are many series, such as Dalea scoparium series of sandy dunes, which are of trivial acreages. There are potential series, such as a Bouteloua curtipendula series, reported in Region 2 (U.S. Forest Service 1982), that possibly exist in Region 3 but lack synecological definition and therefore fall within more general series of table 1. Finally, there are series omitted through oversight or my own ignorance.

An earlier effort to classify series on a comprehensive basis for Region 3 (U.S. Forest Service 1974) was, in my opinion, overly detailed, but lacked definition of the 80 proposed series. As data became available during subsequent years (primarily from TES and habitat type studies) we now appreciate that some of these series were appropriate while others are perhaps better understood as subseries or even plant associations. The vegetation taxonomy employed in this paper is shown in tables 2 and 3 (after UNESCO 1973, U.S. Forest Service 1983).

TABLE 1. Vegetation series on National Forest lands and National Grasslands of Region 3. Series of important geographic extent are given in capitals.

CLIMATIC SERIES	NON-CLIMATIC SERIES	
Geum rossii	Pinus aristata	Chrysothamnus
ABIES LASIOCARPA	Pinus flexilis	Andropogon hallii
ABIES CONCOLOR	Festuca ovina	Prosopis Juliflora*
Pseudotsuga menziesii	Festuca thurberi	Agropyron smithii
PINUS PONDEROSA	FESTUCA ARIZONICA	Hilaria mutica
Pinus engelmanii	Picea pungens*	Deschampsia cacspitosa
Pinus leiophylla	Cupressus arizonica	
PINUS EDULIS	Populus angustifolia*	
QUERCUS ARIZONICA	Plantanus wrightii*	
JUNIPERUS	Populus fremontii*	
Quercus turbinella	Cercocarpus	
Quercus toumeyi	Sarcobatus vermiculatus	
Larrea divaricata	Artemisia filifolia	
CERCIDIUM MICROPHYLLUM	Atriplex canescens	
Artemisia tridentata	Coleogyne ramosissima	
BOUTELOUA GRACILIS	Fallugia paradoxa	
Bouteloua eriopoda	Eurotia lanata	

*Series generally or exclusively on phreatic soils

[1] Paper presented at Workshop on Southwestern Habitat Types, Albuquerque, NM, April 6-8, 1983.

[2] Ecologist, Region 3

1. ALPINE TUNDRA (Unesco Grassland/herbaceous V.C.8 but not limited to high latitudes; BLP 111.5x Rocky Mountain alpine tundra; Küchler 52)[3]

Alpine tundras have not been extensively studied from synecological perspective in Arizona and New Mexico. Until further known all tundra has been provisionally lumped into a single series.

- Geum rosii Series. (Both vadose and phreatic alpine tundras are included here. See BLP 111.5x and 211.5x)

2. CONIFEROUS FOREST (Unesco 1.A.10)

- Abies lasiocarpa Series. This is synonymous on vadose soils to subalpine forest, taiga, spruce-fir, or Engelman spruce-subalpine fir. See Layser and Schubert 1979, BLP 121.31. The series includes both Picea engelmanni and Abies lasiocarpa Series of Region 2.

  Coniferous forests on phreatic soils are also within this series, differing mainly by riparian obligate deciduous species of understory stature (BLP 221.xx).

- Abies concolor Series. Synonymous to montane forest, upper montane, mixed conifer, and Rocky Mountain montane forest (BLP 122.31, Layser and Schubert 1979). On vadose soils both Abies concolor and Pseudotsuga menziesii are characeristically co-climax. Minor acreages mostly north of the Mogollon Rim of Douglas-fir climax are treated as topographic climax within this climatic series.

- Pseudotsuga menziesii Series. This is a minor climatic series generally south of the Mogollon Rim (mostly Coronado and Gila forests). Plant associations have been provisionally described by Moir and Ludwig 1979. This is probably BLP 122.31 or 123.5x.

- Pinus ponderosa Series. Lower montane, Transition of the Merriam life zone terminology, Pine series (BLP 122.32). This is a vadose, climatic series generally of frigid soil temperature regime but also mesic soil temperature regime south of the Mogollon Rim.

- Picea pungens Series. A typically phreatic series of very minor acreage along montane drainages. Populus angustifolia is absent. Blue spruce can also occur on vadose soils within this series (DeVelice et al 1983) BLP 222.xx.

- Cupressus arizonica Series. Minor forest mostly on the Tonto forest in central Arizona. Ecologically poorly known and sometimes referred as a chaparralic post-fire disclimax (cf the Arizona cypress-shrub live oak association of Carmichael et al 1978). The Arizona cypress is variety glabra. Arizona cypress along major streams (var. arizonica) is treated here within the Platanus wrightii Series. BLP 123.52.

- Pinus engelmanni Series.
- Pinus leiophylla Series. These both belong to a pine-oak or oak-pine woodland (BLP 123.32) on vadose soils. An association of evergreen oaks is diagnostic, but since the emergent pines are over 5 m tall the series falls within Unesco I.A.10 (coniferous forest). The canopy is "closed" in mature forests only by assuming oaks to be a component of the overstory. The soil water regime is ustic, and temperature regime probably mesic. These series are important only on the Coronado Forest. See BLP 123.32.

  Where Apache or Chihuahua pines occur with evergreen oaks on Ustifluvents, they are treated within the phreatic Platanus wrightii series (see Moir 1979).

3. DECIDUOUS or MIXED EVERGREEN-DECIDUOUS FOREST (Unesco I.B.2 and I.B.3) These are almost invariably phreatic and commonly along major or permanent water sources.

- Populus angustifolia Series. Includes associations with Picea pungens, Abies concolor, Pinus ponderosa, or P. edulis. In some locations Alnus oblongifolia replaces Populus angustifolia. This is a common series of montane canyons of frigid soil temperature regime. At high elevations it is replaced (at cryic soil temperature regime) by the Abies lasiocarpa series. See BLP 222.31 and 222.32, Rocky Mountain riparian deciduous forest.

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[3] UNESCO(1973), Küchler (1964), and Brown, Lowe, & Pase (1979) classifications are referenced when apparently analogous. The series level digitized classification of the latter is represented by two digits to the right of the decimal. Unnamed series are denoted by an "x" replacing one or more digits.

- Platanus wrightii Series. Includes associations with other conifers (e.g. Cupressus arizonica v. arizonica and Pinus engelmanni and with other deciduous trees. However cottonwoods (Populus angustifolia or P. fremontii) are absent, infrequent, or at best simply codominant with the sycamore. This series (BLP 223. 22) is mostly south of the Mogollon Rim in Arizona and southwestern New Mexico. It is minor in acreage, but as with most riparian forest, important for wildlife and recreation.

- Populus fremontii Series. Includes other broadleafed cottonwoods as geographically appropriate (P. deltoidea, P. acuminata). The common streamside and river gallery forest of grasslands and deserts. The cottonwood-willow series of BLP 223.31. Mesquite bosques (BLP 224.52) and salt-cedar bosques (BLP 234.72) are treated within this series. This series is of only minor acreage on National Forests and along the Canadian River on National Grasslands.

4. CONIFEROUS WOODLAND (Unesco II.A.2). Evergreen oaks are absent or subordinate. The Layser and Schubert (1979) series are adopted in this treatment.

- Pinus aristata Series
- Pinus flexilis Series. Both of trivial acreage above 8500 feet elevation. Pseudotsuga menziesii may be codominant. BLP 121.32.

- Pinus edulis series. Includes Pinus cembroides (P. discolor of some taxonomists) where geographically appropriate. In acreage and geographic extent this is the most important series in Region 3. Pinyon-juniper woodlands and savannas (Küchler 23, BLP 122.41).

- Juniperus Series. Includes J. monosperma, J. erythrocarpa, and J. osteosperma as geographically appropriate. Juniper savannas (BLP 122.41 and Kuchler 23) as well as juniper chaparrals south of the Mogollon Rim and in southern New Mexico (cf Moir 1979). This series is almost as important on National Forest lands as the above.

5. EVERGREEN OAK WOODLAND (Unesco II.A.1). Evergreen oaks dominant or codominant, but pinyons and/or junipers are also usually present. These are the Madrean oak woodlands or Encinal (BLP 123.31) of vadose soils. In addition a canyon oak woodland occurs along phreatic soils (typic and aridic Ustifluvents) of intermittent drainages (Moir 1979, Dick-Peddie and Moir 1970). An overstory of taller pines is absent (see Pinus engelmanni and P. leiophylla series).

- Quercus arizonica Series. Includes Quercus grisea (which hybridizes with Q. arizonica), Q. oblongifolia, Q. emoryi, Q. hypoleucoides, and rarely Q. rugosa singly or in combination. This series is major only in southern New Mexico and south of the Mogollon Rim in Arizona. It is important especially on the Coronado forest. See Daubenmire's (1978) Encinal Province, Layser and Schubert 1979, BLP 123.31. I see no compelling reason to split this series into several evergreen oak series at this time.

6. CHAPARRAL (Unesco III.A.1d)

- Quercus turbinella Series. Centered in the Tonto forest (BLP 133.31 scrub oak; Carmichael et al 1978)

- Quercus toumeyi Series. Minor acreages in the Coronado Forest (BLP 133.31, Moir 1979).

- Cercocarpus Series. A minor chaparral in southern New Mexico (Cercocarpus breviflorus and south of the Mogollon Rim (including other species and varieties of Cercocarpus). See BLP 133.34 and Dick-Peddie and Moir 1970.

7. GRASSLAND (Unesco V, herbaceous communities but including shrubsteppes where the graminoid component is conspicuous).

- Alpine grassland. See Geum rossii Series. Although graminoid tundras exist in Region 3 (common plants include Carex elynoides, Poa rupicola and Festuca brachyphylla), they are not as yet differentiated from other alpine tundra communities.

- Festuca ovina Series.
- Festuca thurberi Series.
- Festuca arizonica Series. These are all within forest climates (forest steppes) and lumped together as a bunchgrass series (BLP 141.41). They are also known as mountain bunchgrass rangelands. Important as summer grazing range, there is appreciable acreage in the Carson, Kaibab, Apache, Gila, and Coconino forests. The regional climate of each series is very distinct. Each series has its characteristic grassland and associated wet meadows. See also Moir 1967. The Arizona fescue series at lowest elevations (frigid soil temperature regime) is most extensive.

- Deschampsia cacspitosa Series. A minor series of subalpine wet meadows, Kaibab, Santa Fe, Carson, and Apache National Forests.

- Bouteloua gracilis Series. Cold temperate grasslands of BLP (142.13 and 142.12) and Daubenmire's southeastern section of the Bouteloua gracilis Province (Daubenmire 1978, p. 202). This series includes codominance with Buchloe dactyloides (Küchler 65, shortgrass steppe), with Hilaria jamesii (Küchler 53, grama-galleta), The grama grasslands of the San Augustin plains (Potter 1957), and a wide variety of piedmont grasslands such as blue grama-curly mesquite (BLP 143.13) or mixed grama piedmonts (Wallmo 1955, Moir 1979).

- Bouteloua eriopoda Series. Warm temperate grasslands of BLP (143.11, 143.15) and the southwestern section of the Bouteloua gracilis Province (Daubenmire 1978, p 202). Relatively poorly studied in all its complexity, the series is broadly known as desert grassland or semidesert grass-shrub range (Martin 1975, Küchler 58, BLP 153.22, Moir 1979). The piedmonts analogous to the above series are virtually unknown synecologically.

- Artemisia tridentata Series. Great Basin shrubsteppe (BLP 142.22) and Kuchler 38. Mostly on the Carson and Kaibab forests.

- Fallugia paradoxa Series. Restricted to volcanic malpais on the Cibola forest.

- Artemisia filifolia Series. Deep sandy soils especially on National Grassland (Küchler 70).

- Andropogon hallii Series. Sandy soils on National Grassland (BLP 142.11 and Küchler 70).

- Agropyron smithii Series. Edaphic series of swales in cool temperate grassland (BLP 142.21). Trivial acreages in Region 3.

- Hilaria mutica Series. Edaphic series of swales in warm temperate grassland (BLP 143.12). Minor acreages on Prescott, Tonto, and Coronado forests.

- Atriplex canescens Series. Minor series on moderately well-drained but slightly alkaline soils.

- Chrysothamnus nauseosus Series. A minor phreatic series of alluvial washes of intermittent drainages. Includes other species of Chrysothamnus on cumulic or fluventic soils within Pinus ponderosa and Pinus edulis climatic series. Also trivial acreages on cumulic or fluventic soils of the Artemisia tridentata climatic series

- Eurotia lanata Series. Edaphic on calcareous soils. Trivial acreages in several national forests.

- Sarcobatus vermiculatus Series. Trivial acreages on heavy textured saline or saline-alkaline soils.

- Coleogyne ramosissima Series. A cold desert (BLP 152.13) of trivial acreage on the Kaibab and Coconino forests where possibly the series exists as edaphic outliers. Ecology poorly known here.

8. DESERT (Unesco III.C.1, mainly evergreen subdesert shrubland; and the Larrea divaricata or hot desert Province of Daubenmire 1978).

- Larrea divaricata Series. This is climatically the Chihuahuan Desert (BLP 153.21, Küchler 44 and 59) with, in addition, calcareous-edaphic representation in the Sonoran Desert (BLP 154.11 Creosotebush-bursage and Küchler 41 and 42). The acreages of this series on National Forest lands are minor.

- Cercidium microphyllum Series. This is climatically the Sonoran Desert (BLP 154.12 Palo verde-Saguaro and Küchler 43). The series on National Forest lands is centered on the Tonto (ca 250,000 acres) with minor acreage on the Coronado forest. The soil temperature regime is thermic with but trivial acreages of hyperthermic at lowest elevations.

- Prosopis juliflora Series. This is an evergreen (in mild winter climates) or deciduous shrubland series along desert washes of intermittent or ephemeral water flow in both Chihuahuan and Sonoran climates. The absence of potential cottonwoods (Populus fremontii Series) helps characterize this desert phreatic series. Other plants are Rhus microphylla, Hymenoclea salsola, and H. monogyra. Possibly BLP 234.71.

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TABLE 2. Vegetation taxonomy for New Mexico and Arizona

TAXON	EXAMPLE	GEOGRAPHY & SCALE	
CLASS	Closed forest	Global	$1:10^{7}$
FORMATION	Coniferous forests	Continental	$1:3\times10^{6}$
SERIES	Ponderosa pine	Western U.S.	1:500,000
SUBSERIES	Ponderosa pine-pinyon-Rocky Mountain juniper	Northern NM	1:24,000
ASSOCIATION	Ponderosa pine/Gray oak	Sangre de Cristo Mts.	1:6,000

TABLE 3. Example of hierarchical vegetation classification for non-phreatic soils in portions of the Santa Fe National Forest.

SERIES	SUBSERIES	ASSOCIATION*
ABLA	Pien-Ablaa	Abies lasiocarpa/Polemonium pulcherrimum
		Abies lasiocarpa/Vaccinium
	Pien-Ablaa-Abco-Psmeg	Abies lasiocarpa/Linnaea borealis
		Abies lasiocarpa/Erigeron eximius
ABCO	Abco-Psmeg-Pipo-Pipu	Picea pungens/Erigeron eximius
		Picea pungens/Festuca arizonica
	Abco-Psmeg-Pipo	Abies concolor/Acer glabrum
		Abies concolor/Quercus gambelii
		Pseudotsuga menziesii/Quercus gambelii
PIPO	Pipo	Pinus ponderosa/Festuca arizonica
		Pinus ponderosa/Quercus gambelii
	Pipo-Pied-Jusc2	P. ponderosa-Pinus edulis/Quercus gambelii
		Pinus ponderosa/Quercus grisea
		Pinus ponderosa/Bouteloua gracilis

*From DeVelice _et al_. 1983

Regional Correlations Among Vegetation Classification Studies[1]

Barry C. Johnston[2]

Abstract.--The methods for classifying plant associations (habitat types) demand correlation of plant associations described elsewhere, yet many workers have neglected it. Similarity among communities is assessed primarily using constancy and cover by species, confirmed by comparison of site attributes.

PLANT ASSOCIATIONS AND HABITAT TYPES

The method for classification of vegetation that we are discussing today had its conceptual beginnings in the study of Daubenmire (1952). Because of the poor organization of seral communities, and the significantly larger number of them, he considered that a classification of climax communities formed the basis of "the most significant biogeographical classification of the land surface." The climax community upon which his classification rested is called the association. Recent editions of Daubenmire's concepts have changed this term to plant association, to distinguish it from soil and other associations (e.g., Buttery 1978).

Daubenmire was not the first to use the term association; but he did pioneer the use of the term habitat type, which he defined as a land unit, "the collective area which one association occupies, or will come to occupy as succession advances" (Daubenmire 1952). Thus an association is a climax vegetation unit, distinguished primarily by its plant species and their composition, whereas a habitat type is a land unit, a vegetation map unit. In the Forest Service, and to a limited extent elsewhere, habitat type has been used with exactly the same meaning as plant association. Because the term habitat type is unfortunate for several reasons (it is used in quite a different sense by wildlife biologists, for example), there is properly a gradual return to the use of association (or plant association) as the basic unit of vegetation classification.

A distinction needs to be made between classification (definition of units called associations) and mapping for an inventory (definition of units called habitat types). The clearest way to see this distinction is to examine the methods used to classify vegetation. The methods have been summarized in Figure 1, with some detail omitted.

One conclusion that immediately can be drawn is that indicators are important at several times during the process. Indicators are usually vascular plant species (not genera), but some very important indicators are landform descriptors, soil characters, or geological substrates (Clements 1920). There does not exist an indicator that is by itself capable of distinguishing two plant associations. There is no species that is everywhere indicator of seral conditions; there is no species that is everywhere indicator of climax.

An especially important set of indicators are those which can be used to indicate disturbance, for it is these that distinguish a classification based on potential (climax) vegetation from one based on present vegetation alone (cover-type classification). These become more important in classification as we move from forest associations to shrublands and on to grasslands and forblands. In these latter physiognomic types, technical detection of the differences between an exotic species and a closely-related native species can be demanding, but necessary.

An important set of indicators in forests are those species which show shade-tolerance or shade-intolerance. In grasslands, on the other hand, soil descriptors are often more important. These ideas should be used to used to direct our vision, to aid field identification of seral communities.

From Figure 1, you can see that detection and use of indicators is a dynamic, iterative process, especially when you are working your way into unknown territory. For this reason, mapping should proceed from the best-known habitat types outward. In a watershed anywhere in much of the southern Rocky Mountains, there will typically be three or four important habitat types, occupying thousands of acres each; in addition there will be 10-20 habitat types each covering much smaller acreage. If the first stands to be sampled are selected randomly or arbitrarily, the crew doing the sample are more likely to be confused. If the plant communities are in large part unknown, it fits the methods better to begin with the large-acreage habitat types, which will be easier to map. Then, after the crew has a good idea of the indicators, proper identification and mapping of the minor habitat types becomes much easier.

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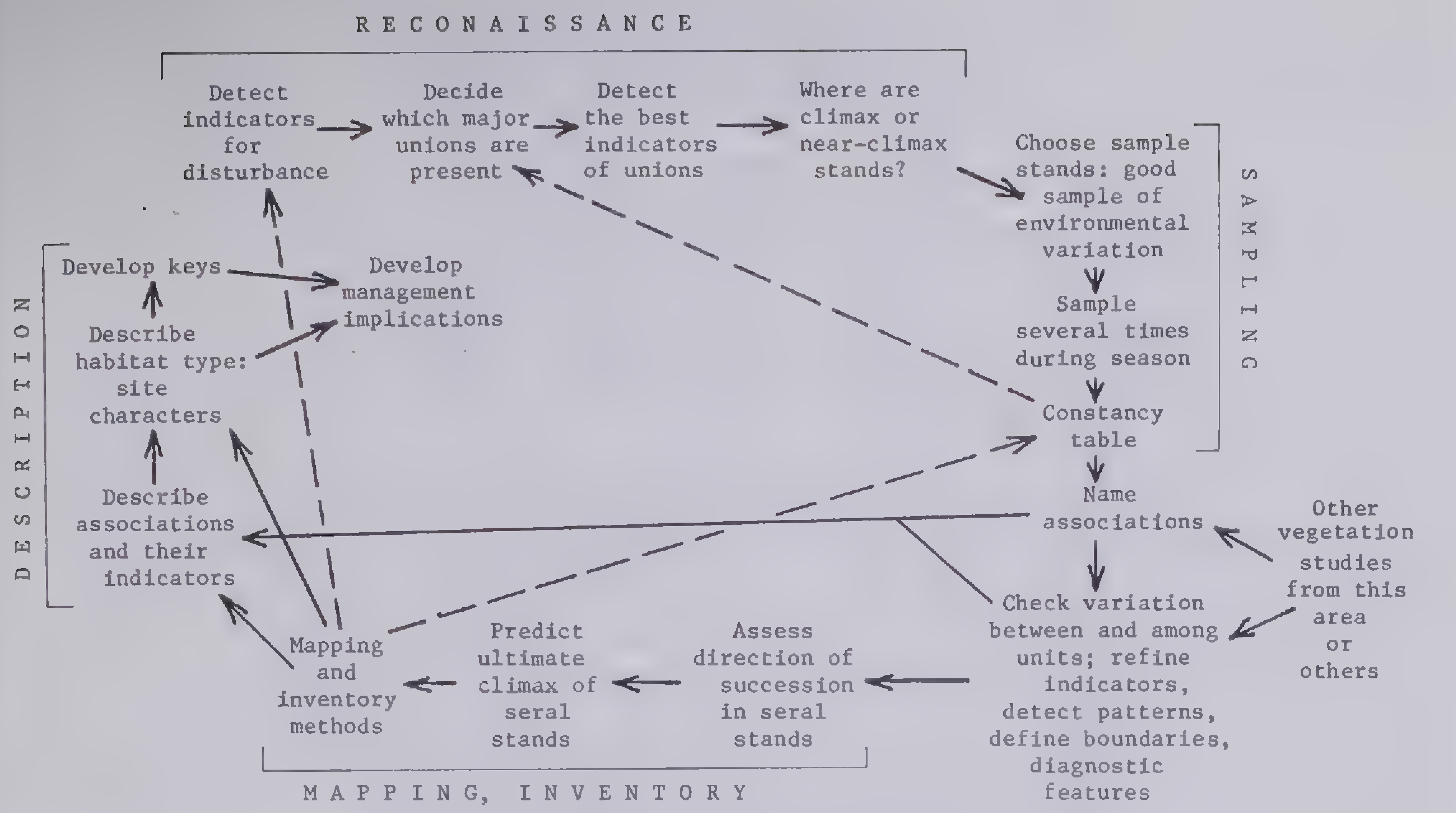

Figure 1.--Methods for classification of plant associations and their habitat types (Daubenmire 1952 and 1970, Daubenmire and Daubenmire 1968, Pfister and Arno 1980).

REGIONAL CORRELATIONS

Figure 1 shows that most investigators would like to allow at least some influence on their classifications, to come from other studies in the same area or different areas. Other investigators, however, have worked more in a vacuum. There are cases where a study has failed to take into consideration a previous study from the same study area, using the same methods. Sometimes, the previous study has never been read or cited! The result is a noticeable lack of uniformity of nomenclature, but what is more important, the reliability of a classification could have been improved with full consideration of as many studies as possible. The resource managers can be understandably confused, and yet discouraged because we have added the burden of understanding a diverse literature to his already heavy load of plant species identification.

Another problem often encountered occurs when a resource manager is reluctant to assign an association to a stand, when that association does not appear on the "official" list for his Forest or Grassland. Sometimes the problem is complicated when he uses only a list of names for identification! A name is only a name, and does not show all the indicators used for identification. Conversely, the species shown in a name may not even be good indicators, although we try to avoid this situation.

We need to make a complete classification, that is capable of expanding into new, unclassified territory and yet work reasonably well. We need to combine data sets for the same ecosystem, so that we increase the power and universality of our classification, and even further refine our ideas of what the true indicators are.

A SIMPLE CASE

You can begin to see how regional correlations work with consideration of a simple case -- in which the same named association has been described from several different areas (Table 1). From the table, you can see that the three studies represent somewhat different approaches, but the differences are not very great. All three studies have stands dominated by *Picea engelmannii*, *Abies lasiocarpa*, *Calamagrostis canadensis*, *Vaccinium scoparium*, *Senecio triangularis*, and *Arnica cordifolia*. The last three species listed are less common in central Idaho. It appears that the Arapaho-Roosevelt National Forest stands have greater variety of wet-site graminoids and forbs. *Pinus contorta* is the leading seral tree in Montana and Idaho, whereas *Populus tremuloides* is in Colorado.

The approach in this case is to start with the vegetation, getting a consensus among all areas as to the identity of the dominants and a few subdominants. Having achieved the consensus, and with some firm ideas about what the vegetation indicators are, then confirmation is sought in the site descriptors -- climate, soil, landform, topography, etc. If a relatively narrow range is found in the types of site where the association is found, over a large distributional area, then there is only one

Table 1.--Constancy, % (CON) and canopy cover, % (COV) in three different parts of the Rocky Mountains, for *Abies lasiocarpa-Picea engelmannii/Calamagrostis canadensis* plant association.

GF*	Species	Western Montana (Pfister et al. 1977) n = 23		Central Idaho (Steele et al. 1981) n = 7		North-central Colorado (Hess 1981) n = 4		Total n = 34	
		CON	COV	CON	COV	CON	COV	CON	COV
T	Abla	100	17	95	10	100		97	(15)
	Pienl	100	39	100	33	100		100	(38)
	Pico	75	21	95	25	-			
	Pial	65	3	-	-	-			
	Psme	+	+	10	1	-			
	Potri	-	-	-	-	50			
S	Vasc	95	28	45	5	100	3	82	20
	Rila	35	1	75	1	100	2	50	1
	Loinl	-	-	-	-	100	2		
	Legl	75	17	-	-	-	-		
	Vamy	+	1	-	-	100	2		
G	Caca	75	21	100	62	100	33	82	31
	Caaq	-	-	-	-	100	10		
	Cadi	-	-	15	3	75	1		
	Lupa	-	-	-	-	75	1		
	Came	-	-	-	-	75	+		
	Cafe	-	-	-	-	75	+		
F	Setr	95	10	15	1	100	2	79	7
	Arco2	85	2	45	1	100	1	76	2
	Smst	0	0	95	2	100	2		
	Eqar	25	1	35	1	100	10	35	2
	Mipe	-	-	35	1	100	1		
	Saar	-	-	0	0	100	8		
	Osde	-	-	65	1	100	1		

* GF = growth form:
T Trees
S Shrubs
G Grasses and grasslikes
F Forbs

\+ = present, but less than 1%
0 = looked for (on the list), but absent
\- = not on the list (uncertain whether looked for)

habitat type for all. In this case, the sites these plant communities occupy are at least as similar as the plant communities on them. These sites are all wet year-round, with high water tables and the soil permanently saturated, on shallowly-inclined pockets and drainages with deep winter snow cover.

Note that we have emerged with a much better picture of what the true indicators of this association are. On the other hand, if you had based your description of the association on only one of these three studies, you could have been misled. Looking only at western Montana, for example, you could have chosen *Ledum glandulosum* as an indicator for this association, and included it in your key -- but this species doesn't grow in the southern Rocky Mountains at all! A similar result would follow from exclusive use of either of the two other studies. The key and description would mean little to someone trying to use it in another area.

All studies of vegetation should be examined for possible inclusion in regional correlation. Of course, data collected using any of the potential association methods or habitat type methods will all be usable. Other studies may be usable in whole or in part. Determine first whether the objective of a study was to sample climax (potential) vegetation. Many studies did in fact do this, in spite of their never having mentioned the question. The results may be the same, even when the only constraint was the need to pare down the large number of present-vegetation communities (cover types) into a manageable number of discrete, recognizable communities.

Secondly, make certain that uniform (homogeneous) plots were sampled, rather than points along a gradient. Some kind of constancy (or frequency) table is nearly always necessary, although once the indicators of an association are fairly well-established, table-less studies can be used to extend its distribution. It is helpful to have both constancy (or frequency) and cover; indices

Table 2.--Constancy, % (CON) and composition, % (COMP) or cover, % (COV) in three different portions of northwestern Colorado, for Quercus gambelii/Symphoricarpos oreophilus-Amelanchier spp. plant association.

GF	Species	Northwest Colorado[1] (Tiedeman 1978) n = 5		White River NF[2] (Hess and Wasser 1982) n = 5		Routt NF[3] (Hoffman and Alexander 1980) n = 3		Total n = 13	
		CON	COMP	CON	COV	CON	COV	CON	*
S	Quga	100	8	100	54	100	10	100	26
	Syorl	100	10	100	28	100	25	100	20
	Amut	100	5	100	23	-	-	77	11
	Amal	-	-	-	-	100	4	23	1
	Rowo	80	2	60	2	33	+	62	2
	Prvi	60	6	80	2	100	7	77	5
G	Cagel	100	26	100	42	67	16	92	11
	Poinl	-	-	40	+	100	2		
F	Viam	100	10	100	9	100	+	100	7
	Gabo	100	5	80	1	33	2	77	3
	Aqca	100	1	-	-	-	-		
	Lipo	-	-	80	4	0	0		
	Luar	80	+	80	1	33	+	69	+
	Lale	-	-	80	1	33	1		
	Erel	-	-	-	-	100	1		
	Acla	40	+	-	-	100	4		

Symbols as in Table 1.
1. Called "Mixed mountain shrub-oak/pachic dark brown loams"
2. Called "Quga/Syorl/Cagel habitat type"
3. Called "Quga/Syorl habitat type"
*. Calculated as a combination of composition (column 1) and cover (columns 2 and 3), not statistically valid

Table 3.--Constancy, % (CON) and canopy cover, % (COV) in three different portions of northern Colorado, for Artemisia tridentata ssp. vaseyana/Festuca idahoensis plant association.

GF	Species	White River NF (Hess and Wasser 1982) n = 5		North-central Colorado (Terwilliger and Tiedeman 1978) n = 6		Arapaho-Roosevelt NF (Hess 1981) n = 4	
		CON	COV	CON	COV	CON	COV
S	Artrv	100	19	100	25	100	33
	Chvi3	20	+	100	3	25	+
	Syorl	40	+	83	1	25	+
G	Feid	100	22	67	3	100	24
	Cahe	40	1	83	8	100	2
	Stoc	100	1	50	1	50	1
	Pofe	-	-	100	7	50	1
	Feth	100	2	-	-	0	0
	Kocr	60	1	83	2	75	1
	Agsp	-	-	83	+	50	1
F	ANTE	100	1	83	1	100	3
	Erum	80	1	100	3	75	1
	Popu	100	2	33	+	25	+
	Viam	100	2	33	1	0	0
	Taof	80	4	50	+	-	-
	Mela	-	-	100	3	50	1
	Phmu	-	-	67	2	0	0
	Cafl	-	-	33	+	75	+

Symbols as in Table 1.

combining them are less useful. The most useful display of data shows both frequency and cover for each plot (or stand). Identification of plants always to species is irreplacable, even in Carex,

Salix, and Poa. The results of such regional correlation are documented in a summary report, such as "The Plant Associations of Region 2" (USDA Forest Service, Region 2, 1982).

DIFFERENT NAMES FOR THE SAME COMMUNITY

A slightly more difficult case is shown in Table 2. Here the three types were given different names in the three studies presented. They have the same dominant species, in spite of the widely different nomenclatoral history. An interesting story emerges here, of the replacement of one species of Amelanchier for another. As in the previous case, basing a description and key on only one of these studies would have resulted in an incorrect interpretation of what the true indicators are.

Another example from shrublands is shown in Table 3. Some further interpretation is possible in this case, because the study by Terwilliger and Tiedeman (1978) showed that all of their six sites had been moderately to heavily used by livestock. The table shows, then, that Chrysothamnus viscidiflorus and Poa fendleriana are increasers with livestock use in this habitat type. This illustrates how, if additional data are included in one of the studies, some of the observations or conclusions can be extended to the other studies, since the assumption that a habitat type is fairly uniform in its potentials and responses to management, is well founded. To take another illustration, the sites where Terwilliger and Tiedeman (1978) sampled were known to be part of critical range for mule deer, which can be generalized to indicate habitat capability in other areas.

CONCLUSIONS

When beginning regional integration, use studies from a wide range of geography and sites, not to exclude any studies deliberately. It is often necessary to extend the correlation to studies outside your particular region of interest, in order to understand the communities within your region, and to increase the size of the effective data base. The general tactic when doing classifications, identifying the habitat types in a watershed, or correlating communities over a region, is to work from the simple to the complex:

from	to
easily-described	obscure (now)
large-acreage	small-acreage
important	not so important
easily identified	indicators not apparent
well-documented	simple lists, uncertain methods
now	later

An observation that can be made from the methods (Figure 1) is that many association classifications and habitat type studies skip directly from the naming of types to their description, jumping over assessment of seral conditions and mapping, and never reaching the development of management implications. Mapping and the development of management implications are an important part of the classification process, since they give the final classification product much more credibility and make the units of classification much more identifiable. My experience has shown that mapping, even just over a small watershed as a test case, improves and sharpens a classification to a great extent. In addition, the credibility of the classification is increased in the eyes of the local resource managers, an important facet of training.

The need of regional correlation for the original plot (stand) data points out the necessity of preservation of that original data in some form. Local managers need to have access to these data as well, to improve their intensive inventories and aid them in identification.

Daubenmire (1952) and workers following him have emphasized the concept of climax as basic to the classification of vegetation. In recent years, the word climax has become more controversial and has sparked many disagreements, mostly concerning whether the projected climax community actually exists in a given situation. For this reason, some have recommended substituting the term classification by potential for the term classification by climax. The argument whether a climax community actually exists is misplaced, however, for the term climax actually describes a method of approach rather than a community. Arguments as to existence of the community should not be allowed to obscure the considerable utility of the method. There is no reason why the method cannot be applied, even where it can be demonstrated that a climax or near-climax community does not exist. In fact, the method has considerable advantage and utility even when we cannot accurately describe the climax community (called potential natural community in the Forest Service Manual).

Many workers have noticed that studies from adjacent or nearly areas using different methods often have results that are closer to each other in classification units than one would expect. This phenomenon is often explained by hypothesizing that this confirms the existence of relatively discrete ecosystems in nature. There is another hypothesis, that nearby studies using different methods are similar, because of a similarity of objectives, all workers trying to produce classification units within which management implications and responses are best represented, in other words, units with the maximum amount of information content about plant species.

The common features to all these studies that produce such similar results do not seem to include classification by climax (potential); neither do they include existence or demonstrability of the climax community. The smallest set of common features that bind us together, and that make correlation of a wide range of different vegetation classification studies possible, can be expressed as only two ideas:

1. Classification by dominance by species in layers, in combination with
2. Diligent and continual use of indicator

species and other indicators, especially indicators of disturbance or lack of disturbance.

I claim that comprehensive use of these two ideas alone results in a classification which can be used to make regional correlations, and therefore one of national significance.

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Reports of Working Groups

REPORT OF WORKING GROUP NO. 1
IMPLEMENTATION OF HABITAT TYPE CONCEPT FOR
MANAGEMENT OF FOREST ECOSYSTEMS IN REGIONS 2 AND 3

TOPIC 1
SITUATION

Habitat Type classifications are sufficiently complete in both Regions to permit use of the system. Region 2 seems to be slightly ahead in time for organizing and encoding the habitat types for use in field level projects. The next step is to make use of Habitat Types to improve management practices.

TOPIC 2
IDENTIFICATION OF HABITAT TYPES IN THE FIELD

A. Training needs:

1. Training in concepts, plant identification, and use of keys should be a RO responsibility for initial workshops to train key Forest and District personnel. Include enough management implications and the potential for derivation of more implications to sell use of the concept.

2. Training of data collectors, contractors, Stage II crews should be a District and Forest responsibility.

B. Additional development needs for implementation of the concept.

1. Develop Keys and Checklists for specific geographical areas such as Forests or groups of Forests.

2. Develop codes for each habitat type to use in data collection systems (Stage II), stand record systems, functional data bases (RUN WILD) and other information systems.

3. Develop pocket field guides for use in field.

4. Change functional Handbooks that may be affected.

a. Silvicultural Exam and Prescription
b. Range
c. Wildlife
d. Ecosystems

5. Change or create forms that may be needed.

a. Stand exam field sheets
b. Silvicultural prescription checklists
c. Stand record inputs

6. Change or develop contract specifications to incorporate habitat types into Stage II contracts.

C. Mapping.

1. Initial mapping should be for the project areas.

a. Timber sales
b. Wildlife Habitat
c. Reforestation
d. TSI
e. Transitory Range Improvement

2. Detailed mapping of large areas such as Districts or Forests is not an immediate problem. The need for it and methods for doing it are expected to evolve over time.

TOPIC 3
APPLICATIONS OF HABITAT TYPES IN THE FIELD

A. Silvicultural Prescriptions.

1. Prediction of overstory and understory response.
2. Reforestation potentials and species choices.
3. Production potentials.

B. Wildlife Habitat Improvement.

1. Kinds and duration of seral communities.
2. Prediction of population responses to vegetation treatments.

C. Range Improvement.

1. Productivity predictions for transitory ranges.
2. Effects of grazing on other resource values:

a. Reforestation
b. Water quality
c. Wildlife forage

D. Land Management Planning.

Habitat types are not likely to be useful until understood and applied at the field level for a period of time. Could not realistically be tested and mapped until the next round of Forest Plans.

E. Extrapolation of Research Results.

1. Identify habitat types for all new studies affecting forest vegetation.

2. Revaluate old studies in light of habitat types to permit better extrapolation of results.

F. Management Implications. Responsibility of all organizational levels and research. Develop implications for all major resources affected by vegetation treatments by means of:

1. Accumulated field experience.
2. Summary of research results.
3. Intuitive judgments based on ecological knowledge of seral relationships within a habitat type.
4. Experience on similar habitat types in other parts of the Rocky Mountains.

Summary of implications into tables and Handbooks for use in the field is a Regional Office responsibility.

TOPIC 4
RESPONSIBILITIES BY ORGANIZATION LEVEL

A. WO. Finalize Manual supplement.

B. RO.

1. Initial training.
2. Change Handbooks, forms and procedures.
3. Assign codes for each habitat type.
4. Summarize management implications and maintain the summary as information is accumulated.

C. SO.

1. Maintenance training.
2. Quality control and checking.
3. Facilitation of District data collection efforts.

D. District.

1. Data collection.
2. Project mapping.
3. Silvicultural prescriptions and interpretation of management application.

E. Research.

1. Relate current and past research to the appropriate habitat type.
2. Develop management implications from knowledge and experience with the habitat types.

REPORT OF WORKING GROUP NO. 2
REGIONAL CORRELATIONS OF HABITAT TYPES

TOPIC 1
METHODS AND PROCEDURES FOR APPROACHING THE PROBLEM

There was general agreement that the approach should be to compare species composition (by constancy and cover) of the vegetation. After having analyzed the studies being compared, and having assessed their similarity, then environmental (site) characters can be compared. If there is a high degree of similarity in environmental characters as well, the feeling was that we could call them the same.

Several problems were identified:

1. We agreed on constancy and cover of vegetation, temperature, moisture, elevation, aspect, slope, soil drainage, productivity, management responses, and floristic composition as criteria for similarity. We also agreed that physiognomic similarity should be assessed after environmental characters were compared. This is not meant to be a comprehensive list, but rather the most important factors. We had difficulty prioritizing them, or quantifying them, but the feeling was that we could not do so. The situation will dictate what combination of criteria must be used.

2. We need to standardize nomenclature for habitat types. A few felt that the Washington Office should coordinate this, through simply compiling all names that have ever been used, with their descriptions. Several people felt that the formal nomenclature of phytosociology should be adapted, to produce rules for nomenclature. Some felt, alternatively, that addition of a geographical indexing code to a habitat type name would serve to distinguish different studies from different areas. There was discussion about what form this code could take, with no resolution of the problem. State names were suggested, or codes for (Bailey) ecoregions; neither were found acceptable. A number assigned to geographical zones by habitat type on a case-by-case basis was suggested, but was deemed not standardized enough to be accepted by all.

We definitely agree with the suggestion that Regions should work more closely on coordinating habitat type nomenclature. There was some expression of the notion that perhaps a small amount of enforcement is indicated, but this idea was not accepted by everyone (it was not discussed fully). The needed increase in coordination among Regions means not only more meetings such as this one, but also more coordinated training sessions, coordinated field data collection, and freer exchange of reports and data sets among Regions.

In general, there was agreement that the conventions for nomenclature of associations need at least to be carefully written down. Some felt that the Regions should work on unifying these methods and conventions. We concluded unanimously that citation of nomenclatoral synonyms and literature references for them should be a minimum standard for all descriptions of habitat types.

TOPIC 2
AT WHAT LEVEL SHOULD REGIONAL CORRELATION TAKE PLACE?

The problem was noted that some studies describe habitat types, which have been described as phases of habitat types in other studies. This is an added complication and special case of the topic question.

There was general agreement that inter- and intra-regional correlation should take place first and primarily at the plant association level. There was general agreement that in cases where the splitting of habitat types into phases raises the question whether these should be separate habitat types or phases, that in those cases a larger number of smaller units should be used, at least initially in the correlation process.

Later, correlation should also occur at the series level, and should make use of criteria and principles learned from the association correlation.

We agreed that correlation at the series level is a very important activity. The news that Dick Driscoll is now going to tackle this Nationally was well received.

There was agreement, or at least no disagreement, that the only proper use and the best purpose of the series level of classification, was to enable upward aggregation of habitat types into larger units, for planning and National assessment.

REPORT OF WORKING GROUP NO. 3
HABITAT TYPES FOR WILDLIFE MANAGERS

TOPIC 1
HOW CAN HABITAT TYPE INFORMATION BE INCORPORATED INTO THE RUN WILD DATA STORAGE AND RETRIEVAL SYSTEM?

RUN WILD is a "library" of information used by wildlife biologists and managers in the Southwstern Region. Details of the database are provided in the User's Manual for the RUN WILD III Data Storage and Retrieval System (U.S. Forest Service Southwestern Region, Wildlife Unit Technical Report, August 1982, 68 p). Most wildlife personnel employ the Brown, Lowe, and Pase classification system, but the database is structured to allow use of any classification system. The general sentiment was that at the Series vegetation level the Brown, Lowe, and Pase system is mostly compatible with Series within the Terrestrial Ecosystem Survey classification (which includes the Plant Association and its corresponding habitat type). Crosswalking the two systems is relatively easy to do and a desireable goal. At the Association level there may be more plant associations than are provided for by the digitizing system of Brown et al.

There may be no compelling reason why actual numerical data for the habitat type studies should be documented within RUN WILD III. However, the literature citations of these habitat type publications (when available) should be part of the RUN WILD library. The updated database for RUN WILD III should include the standard plant association names defined by the habitat typing studies. At present, for example, mostly obsolete names are used for plant associations listed within the Forest Formation (p. 35 of the above cited User's Manual). In addition some plant associations outside the Forest Formation may not be defined by published or accessible data bases, and we are merely left with an association name rather than its description. One goal of RUN WILD should be to reduce this confusion.

TOPIC 2
HOW ARE SERAL COMMUNITIES TREATED WITHIN THE HABITAT TYPE CONCEPT?

Seral stages are often the greatest concern for wildlife habitat or as wildlife mapping units. The next step in habitat type classification is to describe the seral stages for the plant associations. Within each plant association the community types must be related, as best we can, to the plant association. Rates of change (succession) must be studied and quantified and ultimately built into the classifications. For example, aspen communities may be either short or prolonged stages of a coniferous forest sere, depending upon the habitat type.

TOPIC 3
WHAT IS THE DIFFERENCE BETWEEN WILDLIFE HABITAT AND HABITAT TYPE?

This is merely semantics. Any wildlife population usually exploits the resources over a variety of environments or habitat types. This collection of habitat types used during the life cycle of an organism is informally referred to as its habitat. A habitat type is an abstraction from the real world used to partition land areas into units of relatively homogeneous vegetation potential.

TOPIC 4
HOW CAN WE DEVELOP A COMMON LANGUAGE FOR COMMUNICATING WILDLIFE KNOWLEDGE AND CONCERNS?

The RUN WILD system is a good start but mostly used by wildlife personnel in Region 3. Wildlife, timber, range, soil, and watershed personnel should jointly participate in classification seminars and workshops. Crosswalking between different ecological classifications is helpful. Plant associations, community types, vegetation subseries, or Terrestrial Ecosystem Survey mapping units are all better communicated if names for the same units are standarized and, perhaps more important, the names are accompanied by clear, synoptic descriptions of their important and distinguishing ecological attributes (whether vegetation, soil, landform, or whatever).

REPORT OF WORKING GROUP NO. 4 HABITAT TYPES AND THE TERRESTRIAL ECOSYSTEM SURVEY

GENERAL TOPIC

During the last 10 years or so the Southwestern Region has been involved in what appeared to be two separate ecological inventory and classification efforts. As made clear, however, in Chapter 2 of the Terrestrial Ecosystem Survey Handbook, the definitions, concepts, and implementation of the Terrestrial Ecosystem Survey are nearly identical to those employed in the Daubenmire school of habitat type classification. This working group explores the integration of these rather independent data gathering and ecological classification efforts. The key to understanding why both are, in fact, the same ecological classification lies in the hierarchical vegetation taxonomy employed by both habitat type (HT) and Terrestrial Ecosystem Survey (TES) classifications.

TOPIC 1

TAXONOMIC AND MAPPING UNITS

The taxonomic units employed in habitat typing and by TES are as follows (see also Moir, A series vegetation classification for Region 3, this proceeding):

VEGETATION		SOILS
Class		Order
Formation		Suborder
Series		Great group
Subseries	←1:1→	Subgroup (modifier)
Association		Family

TES correlates vegetation and soils at the Subseries level of vegetation taxonomy. A mapping unit for TES consists of a soil unit (soils subgroup with modifier) plus a vegetation unit (Subseries) plus a phase designation (for example, a slope, erosion, or textural class). TES and habitat typing use the same classification system for determining vegetation taxons. The basic difference between TES and HT is at the categorical level chosen for vegetation description and mapping. TES describes and maps at the Subseries vegetation level; HT at the association level. The cover photo of this Proceedings shows three plant associations on contrasting soils and landforms of the Rio Puerco drainage in New Mexico. When plant associations are mapped onto the landscape at this local scale, a habitat type map results (a habitat type is all land capable of supporting the same plant association). Such HT mapping is detailed and expensive--often prohibitive for Forest-level planning at scale 1:24,000. Therefore TES maps at the Subseries level. Since plant Associations aggregate into Subseries, the two mapping systems are the same in Region 3. HTs, without a systematic relationship to soils, have been used to map landscapes (mostly at project levels). The vegetation component of the HT, the plant association, was consiiered the best integrator of environmental and biotic complexity associated with a particular terrestrial ecosystem. TES adheres to the concept of HT, yet identifies a 1:1 relationship between soil and vegetation. This is accomplished by identifying the climatic controls over vegetation (at the Subseries) and soil (Subgroup with modifier).

Example of a TES map unit:

Map Unit No.	Name
50	Typic Haplustalf, HSC,(0) fine, mixed, mesic, fine sandy loam: Pied-Jumo; 15-40% slopes.

TOPIC 2

MANAGEMENT INTERPRETATIONS AT DIFFERENT SCALES

Figure 1 from two TES life zones illustrates opportunities for identifying management at different scales.

The example illustrates effects of climate at the dry/warm limits for ponderosa pine. Soils in life zone 10 have minimal effect on timber production potential. In life zone 11 soil nutrient regimes exert a controlling effect on production potential. At the scale of the plant association contrasting habitat types, on the varieties of soils indicated as Subgroups, may exert strong effects on wildlife or livestock opportunities as suggested by contrasting herbage production classes. Although plant associations differentiate in part of the basis of soils, such soil differences are usually too subtle for us to measure and describe.

Life Zone	10		11	
Subseries	PIPO PIED QUGA JUMO		PIPO QUGA	
Subgroup Modifier Site Index	Lithic Eutroboralfs HSC, (-1) 45		Lithic Eutroboralfs HSC, (0) 55	
Subgroup Modifier Site Index	Typic Eutroboralfs HSC, (-1) 50		Typic Eutroboralfs HSC, (0) 70	
Subgroup Modifier Site Index	Typic Ustorthents HSC, (-1) 45		Typic Ustorthents HSC, (0) 55	
Association	PIPO/BOGR2	PIPO-PIED/QUGA	PIPO/FEAR2	PIPO/QUGA
Herbage Production	Fair	Poor	Good	Fair

Figure 1. Some management interpretations in two life zones of the Southwest at both Subseries and Association levels of ecosystem resolution.

TOPIC 3

TRAINING IN THE USE OF TES AND HT

These ecological classifications and their technical procedures and language are difficult to communicate and understand. This is because the subject of ecosystems concerns the complex and highly variable machinery of nature. Nevertheless resource managers need to know soil-vegetation relationships, biotic potentials and management limitations or opportunities. Training can emphasize principles, major relationships between soils, vegetation, and climate, how management implications are developed, concepts of life zones and limiting factors without bogging down into technical complexity. The Regional Office should promote a well-organized set of seminars, talks, or workshops to be carried to Forest levels on the development and applications of ecological classifications.

REPORT OF WORKING GROUP NO. 5
HABITAT TYPES IN NON-FORESTED ECOSYSTEMS

TOPIC 1
SHOULD THE HABITAT TYPE METHOD BE APPLIED TO NON-FORESTED ECOSYSTEMS, OR ALTERNATIVELY, SHOULD OTHER METHODS BE USED?

There was unanimous agreement that the habitat type method must be applied to non-forested ecosystems. Daubenmire himself (1970) did so with great success. From the point of view of District personnel, use of one method for forested ecosystems and another for non-forested would be confusing.

Thus the choice is not either habitat type methods or another, but rather how we can restructure and adapt habitat-type ideas to solve the problems of classification of non-forested vegetation.

Several people pointed out that the use of the terms "forested" and "non-forested" was confusing to some. The meaning of these terms as this working group used them has nothing to do with commercial forest land, neither does it have anything to do with proclaimed National Forests. We agreed that the proper distinction here was between ecosystems dominated by vegetation in tree form, versus ecosystems dominated by shrubs and herbs.

TOPIC 2
WHAT MODIFICATIONS AND ADDITIONS NEED TO BE MADE TO HABITAT TYPE METHOD TO ADAPT IT TO NON-FORESTED ECOSYSTEMS?

1. Need to intensify the search for relict stands, and urgently so.

2. Need to work with retaking old photographs and other historical records. If possible, make use of the U. S. Geological Survey's Photograph Library.

3. Need to field-check old study plots.

4. Due to the inherent dynamic patchiness of some grasslands, you may have small homogeneous plots to work with.

5. Age-class distributions can still be used for shrubs.

6. You need to be much more careful about species identifications in non-forested ecosystems. This is not to say that identification is unimportant in forested ecosystems; care is necessary in both cases.

7. You need to be much more diligent in searching out indicators. Need to expand search for indicators beyond vegetation into landforms, soils, moisture relations, etc.

8. Search for exclosures and other undisturbed stands needs to be very careful, and should include areas outside the study area: anything you can get! Seek permission to study stands on private land, if undisturbed stands are to be found there. The study area itself needs to be carefully delineated to make a natural unit, not arbitrarily (administrative or State boundaries make poor study area limits).

9. Ability to find a stand at or near climax should not be a prerequisite for use of the term "habitat type."

There was agreement that in some habitat types we may never be able to describe the climax association. That should not prevent us from using habitat type methods to define and delineate habitat types which have distinct responses and potentials on the ground. Diligent use of indicators at every stage in the process will ensure that our best estimate to the association will be reasonably close to the climax potential natural community.

There need to be more plots per habitat type in non-forested ecosystems, and for each plot more data needs to be collected (more characters). Because of the common lack of stands near potential, the climax approach and the evaluation of seral communities may need to be done at the same time. We need to keep striving to know what PNC is, while realizing that we may not know it soon.

There is a greater need here to consider time, fire, and changes in water relations, than there is in forested ecosystems.

Calling zootic communities or disclimaxes habitat types is discouraged. Often, one of these occupies several true habitat types; these can be discerned and separated using careful detection of soil, landform, and water indicators.

TOPIC 3
SHOULD HABITAT TYPE STUDIES INCLUDE MAPPING?

Here people were divided. Some felt that classification should be kept separate from mapping, but most saw that it had some promise. We agreed that mapping for a project or special problem could be used to validate, update, or refine a classification. Indeed, certain problems lend themselves naturally to a mapping solution. Most felt that mapping following a classification, even on a test case of a watershed or other smaller area, was useful. When mapping is done, the results should be input to site-level District data bases, so that it need not be done again.

TOPIC 4
SHOULD FIRE BE PART OF AN ECOSYSTEM FOR HABITAT-TYPE CLASSIFICATION PURPOSES?

We had general agreement that it should, but we recognized that that meant that we must work out the natural frequency of fires in prairie and other grasslands.

Our perception of what the true association is would probably not change very much between leaving

fire out of the picture, and putting it in. We had already agreed that we may not know the association precisely, anyhow. Meanwhile, we would be able to describe the role of fire and responses to it, as part of the management implications to be developed for each habitat type. We agreed that fire roles and responses should be developed per habitat type, and not per some larger unit of vegetation.

TOPIC 5
GENERAL OBSERVATIONS

1. Stump fields and large burns that are not regenerating: are they forest? We agreed to call them forested habitat types only if that most accurately reflected their site potential. In any case, we should note in the inventory that they are being semi-permanently kept in a grass or shrub vegetation.

2. What is the origin of small mountain meadows surrounded by forest? There was no agreement here, although invasion or carbon layer in the soil on each site is strong evidence for calling them forested habitat types. Without such convincing evidence in an individual case, however, there seems to be no need to call them forest; many of them have vegetation and soil characteristics distinct from the surrounding forest.

3. There was some discussion on the role of management goals in a classification. Some felt that management goals should have no impact on classification. Note that we are not saying that resource managers should not be consulted at all stages of a classification; rather, the goals of management should not constrain the definition and delineation of habitat types as units. On the other hand, data recorded and collected during the classification should be in a form that can be used most effectively by resource managers, to help them make decisions more effectively.

Some said that, when making a vegetation classification, we need to classify using vegetation alone, insofar as possible. Management goals have no place here.

There were some who saw that the mapping phase of classification was impossible to do without knowing for what purposes management wished to use the inventory. These people presumably felt that management goals were necessary to be able to do a classification.

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Fourteen papers and five working sessions indicate the state-of-knowledge of ecological classifications and their application in western United States. Some recent concepts of habitat types are examined, and habitat typing as a methodology is compared and related to other ecological classifications that have matured in Southwestern United States in the last decade. The working sessions consider the implementation of these classifications to resource management and planning.

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